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CONTENTS

SPACING TRIALS ON BANANA IN WEST BENGAL

K. C. BHAN and P. K. MAZUMDER

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Received: July 22, 1960

THE planting distance used for banana varies a great deal throughout India, depending on the variety grown and the duration for which a plantation is retained. Proper spacing is of the utmost importance in perennial crops, for it not only affects the out-turn and its quality but also influences the economic life of the plantation, besides modifying the management practices. Spacing trials were conducted to gather preliminary information which might be of value in undertaking more extensive trials in future for both tall and dwarf varieties of banana commonly grown in West Bengal.

It appears that little experimental work has been done on the spacing of banana, for such trials require relatively large plots of land and involve considerable expense. In spacing trials conducted in the French Cameroons, Borel (1952) found that 2·85 by 2·85 metre spacing with controlled suckering was found most suitable for Gros Michel banana. Champion (1953) concluded, from experiments with dwarf bananas conducted at the I.F.A.C. Central Station at Kindia in the French Guinea, that the planting density could be increased up to 2,700-3,000 plants per hectare without adversely affecting the mean yield per plant. Eastwood (1952) reported that in his experiments on Cavendish banana in Queensland, Australia, the highest yield per unit area obtained was from 9 ft. by 10 ft. planting, though wider spacings produced bigger bunches. Extensive spacing trials conducted by the Department of Agriculture, Jamaica, with Lacatan variety have shown that $7\frac{1}{2}$ ft. $\times$ $7\frac{1}{2}$ ft. (810 plants per acre) or closer spacing resulted in the reduction of yield compared with $8\frac{1}{4}$ ft. $\times$ $8\frac{1}{4}$ ft. (640 plants per acre) or wider spacings; closer spacing seemed to prolong the period of maturity (Osborne, 1953).

A brief mention of the spacing practices followed in different banana-growing regions may be of interest. Pope (1926) recommends spacings of 6-10 ft. for dwarf and at least 14 ft. for tall varieties in Hawaii. It is a common practice to plant bananas 18 to 24 ft. each way in Central America, and about 15 ft. $\times$ 15 ft. in Cuba and Jamaica (Reynolds, 1927; cited by von Losecke, 1949). However, according to Popenoe (1941) the spacing is 15 ft. $\times$ 15 ft. and sometimes 16 ft. $\times$ 16 ft. or even 18 ft. $\times$ 18 ft. in Central America, and 11 ft. $\times$ 11 ft. in Jamaica. In Brazil the plants are usually set at 10 ft. $\times$ 10 ft. or 10 ft. $\times$ 11 ft. (Wardlaw and McGuire, 1933).

In Madras State, bananas are usually planted 7-8 ft. apart (Jacob, 1939). Mausitius, a dwarf variety is, however, spaced 5-7 ft. (Naik, 1949). Bananas are spaced 9 ft. $\times$ 9 ft., accommodating nearly 550 plants per acre, in Travancore (Jacob, 1942). In the Amraoti district of Madhya Pradesh Cavendish variety is planted 5 ft. $\times$ 6 ft. (Rao, 1947). Gandhi (1957) stated that in Bombay State Basrai (Cavendish banana) is planted 6 ft, apart both ways, but in East Khandesh, which has

relatively dry climate, the distance is reduced to $4\frac{1}{2}$-5 ft. In Bihar, 10 ft. × 10 ft. spacing is usually practised (Roy, 1950). However, in West Bengal growers use wider spacings—12 ft. × 12 ft. for tall and 9 ft. × 9 ft. for dwarf varieties.

MATERIAL AND METHODS

Spacing trials on banana were conducted separately for tall and dwarf varieties, on a well-drained loamy soil at Krishnagar in West Bengal. The trial representing the tall group was on the Champa and the Martaman varieties, whereas the one for the dwarf group was represented by Kabuli.

The trials consisted of the following spacings:

Spacing	Density of plants per acre
A. *Martaman and Champa*	
(a) 9 ft. × 9 ft.	535
(b) 12 ft. × 12 ft.	330
B. *Kabuli*	
(a) 6 ft. × 6 ft.	1200
(b) 8 ft. × 8 ft.	680

The layout of the trial on Martaman and Champa was randomised blocks with four replications. Each subplot was 36 ft. × 36 ft., accommodating 16 plants in the 9 ft. × 9 ft. and nine plants in 12 ft. × 12 ft. spacings. The trial on Kabuli was planted in paired plots with six replications. Each subplot was 24 ft. × 24 ft., accommodating 16 plants in the 6 ft. × 6 ft. and 9 plants in the 8 ft. × 8 ft. spacings. There was a border row all round the experimental area.

The trials were planted on the July 20, 1950, and continued for about five years. During this period the plant and the three ratoon crops were harvested. The plants were fertilised uniformly at the rate of 8 oz. of N per stool annually, half the quantity of N supplied as ammonium sulphate and the remaining as well-rotted cowdung or town compost. Desuckering was done regularly so as to permit only two suckers per stool.

RESULTS

Growth: The height and the girth measurements recorded in September, 1951 did not disclose any significant differences as influenced by the treatments in any of the varieties (Table I).

Yield: Both the Martaman and the Champa varieties yielded higher per plot when planted 9 ft. × 9 ft. than in the case of 12 ft. × 12 ft. throughout the duration of the experiment (Table II). Interestingly, with closer spacing there was statistically no significant reduction in the per plant yield of Martaman during the period of study; however, Champa showed significant deterioration in the yield per plant in the third ratoon crop.

TABLE I. EFFECT OF SPACING ON THE GROWTH OF THE MARTAMAN AND CHAMPA VARIETIES (CENTIMETRES)

Mean	Varieties / Spacings: Martaman 12 ft. × 12 ft.	Martaman 9 ft. × 9 ft.	Champa 12 ft. × 12 ft.	Champa 9 ft. × 9 ft.	Critical difference P=0·05	Remarks
Height:						
September, 1952	217·17	215·8	191·22	199·75	..	Not significant
Girth:						
September, 1952	62·87	61·87	47·05	47·81	..	-do-

TABLE II. EFFECT OF SPACING ON THE YIELD OF THE MARTAMAN AND CHAMPA VARIETIES (POUNDS)

Crop	Varieties / Spacings: Martaman 12 ft. × 12 ft.	Martaman 9 ft. × 9 ft.	Champa 12 ft. × 12 ft.	Champa 9 ft. × 9 ft.	Critical difference P=0·05	Remarks
Yield per plot (36 ft. by 36 ft.)						
Plant crop	175·75	355·20	145·87	256·37	43·41	**Significant
1st ratoon	247·00	452·68	290·65	497·77	43·75	-do-
2nd ratoon	242·50	398·25	226·50	357·12	54·42	-do-
3rd ratoon	240·12	396·80	251·67	411·37	25·80	-do-
Mean	226·34	400·73	228·67	380·65	..	..
Yield per plant						
Plant crop	19·52	22·20	16·15	16·00	2·91	**Significant
1st ratoon	26·90	28·10	32·27	31·10	3·52	*Significant
2nd ratoon	26·87	24·82	25·12	22·27	..	Not significant
3rd ratoon	26·65	24·75	27·92	25·65	2·12	*Significant
Mean	24·98	24·96	25·36	23·75	..	..

*Significant at P = 0·05
**Significant at P = 0·01

TABLE III. YIELD PER PLANT OF THE MARTAMAN AND CHAMPA VARIETIES (POUNDS)

Source	Degrees of freedom	Sum of squares	Mean squares	F
Blocks	3	101·65	33·88	..
Varieties	1	3·65	3·65	..
Spacing	1	12·33	12·33	1·99
Ratooning	3	1,061·82	353·94	54·87**
Interactions				
Varieties × spacing	1	8·64	8·64	1·33
Varieties × ratooning	3	173·27	57·75	8·95**
Spacing × ratooning	3	35·71	11·90	1·84
Varieties × spacing × ratooning	3	3·63	1·21	..
Error	45	290·59	6·45	..
Total	63	1,691·29		

**Significant at P = 0·01

Interaction: Combined analysis of variance of the Martaman and the Champa varieties for the plant and the ratoon crops disclosed a pronounced effect of ratooning on the per plant yield (Table III). The interaction between varieties and ratooning was found highly significant. The first ratoon crop of both the varieties yielded the highest. However, the decline in the yield of the successive ratoon crops, especially with closer spacing, was greater in Champa compared with Martaman. There was, on the other hand, no interaction between varieties and spacing, or spacing and ratooning.

TABLE IV. EFFECT OF SPACING ON THE YIELD OF THE KABULI VARIETY (POUNDS)

Crop	Spacings		Critical difference P = 0·05	Remarks
	8 ft. × 8 ft.	6 ft. × 6 ft.		
Yield per plot (24 ft. × 24 ft.)				
Plant crop	119·10	190·13	57·92	*Significant
1st ratoon	230·91	435·97	43·02	**Significant
2nd ratoon	164·25	298·33	21·43	–do–
3rd ratoon	169·50	296·86	26·65	–do–
Mean	170·94	305·32		
Yield per plant				
Plant crop	13·23	11·88	..	Not significant
1st ratoon	25·65	27·24	..	–do–
2nd ratoon	18·20	18·60	..	–do–
3rd ratoon	18·76	18·50	..	–do–
Mean	18·96	19·06		

*Significant at P = 0·05
**Significant at P = 0·01

Kabuli, a dwarf variety, also produced higher yield per unit area when planted 6 ft. × 6 ft. than in the case of 8 ft. × 8 ft. in the plant and the three successive ratoon crops (Table IV). There was, however, no significant deterioration in the yield per plant throughout the period of study. As with Champa and Martaman, the yield of Kabuli in the plant crop was poor, whereas, the first ratoon yielded the highest followed by a sharp reduction in the output of the second ratoon crop. The third ratoon crop, however, did not show any further decline in the yield.

Hands and fingers: Observations made during the plant and the third ratoon crops did not disclose any significant reduction in the number of hands and fingers per bunch as a result of closer spacing in all the three varieties studied (Tables V and VI).

TABLE V. EFFECT OF SPACING ON THE NUMBER OF HANDS AND FINGERS PER BUNCH OF THE MARTAMAN AND CHAMPA VARIETIES

Mean	Varieties / Spacings				Critical difference P = 0·05	Remarks
	Martaman		Champa			
	12 ft. × 12 ft.	9 ft. × 9 ft.	12 ft. × 12 ft.	9 ft. × 9 ft.		
Hands						
Plant crop	6·15	6·27	8·25	8·17	0·88	**Significant
3rd ratoon	7·55	7·57	9·90	9·75	0·92	-do-
Fingers						
Plant crop	91·27	90·85	112·05	113·52	18·41	*Significant
3rd ratoon	103·50	100·05	152·37	152·45	20·85	**Significant

*Significant at $P = 0·05$
**Significant at $P = 0·01$

TABLE VI. EFFECT OF SPACING ON THE NUMBER OF HANDS AND FINGERS PER BUNCH OF THE KABULI VARIETY

Crop	Spacings		Critical difference P = 0·05	Remarks
	8 ft. × 8 ft.	6 ft. × 6 ft.		
Hands				
Plant crop	5·51	5·28	..	Not significant
3rd ratoon	6·05	6·22	..	–do–
Fingers				
Plant crop	55·35	50·85	..	–do–
3rd ratoon	84·45	84·68	..	–do–

DISCUSSION

With the closer spacing, 9 ft. × 9 ft., both the Martaman and the Champa varieties produced a higher yield per unit area during the plant and the three successive ratoon crops covering a period of about five years, on an average, to the extent of 77·0 and 66·4 per cent, respectively, than when planted 12 ft. × 12 ft. (Table II). Similarly, the dwarf Kabuli variety yielded 78·6 per cent higher per unit area when planted 6 ft. × 6 ft. compared with the 8 ft. × 8 ft. planting (Table IV). It is noteworthy that with closer spacing the mean yield per plant of the Martaman and the Kabuli varieties did not show statistically significant deterioration throughout the duration of the experiment. However, Champa showed definite signs of decline in the yield in the third ratoon crop. The increase in the yield of Champa as a result of closer spacing was not proportional to the increase in the plant density, which indicated that Champa deteriorated faster than the other two varieties. Similar results were obtained with Lacatan by Osborne (1953) in Jamaica.

These findings are of considerable value to the banana grower, for the local method of planting tall varieties of bananas 12 ft. × 12 ft., or even farther apart, is apparently a wasteful practice. It is likely that with closer spacing deterioration in the yield, especially of the Champa variety which is usually ratooned for a long time, sometimes even for four to five decades, may gradually increase. However, the trend in the deterioration of yield with closer spacing, as observed in the present studies, would indicate a long period of economical cropping before the yield reached a marginal level, provided high soil fertility was maintained. An increase in the density of plants will, of course, increase demand for maintaining adequate soil moisture and fertility.

SUMMARY

Spacing trials on two tall and one dwarf varieties of banana were conducted at Krishnagar in West Bengal. The results obtained during the plant and the three successive ratoon crops showed that the tall varieties, namely, Martaman and Champa, planted 9 ft. × 9 ft. yielded, on an average, 77·0 and 66·4 per cent, respectively, more per unit area than when planted 12 ft. × 12 ft. Similarly, Kabuli, the dwarf Cavendish, produced 78·6 per cent higher yield with 6 ft. × 6 ft. spacing than with 8 ft. × 8 ft.

It is noteworthy that with closer spacing the mean weight of bunches of the Martaman and the Kabuli varieties did not show any statistically significant deterioration throughout the duration of the trial. However, Champa showed significant reduction in the yield in the third ratoon crop. The number of hands and fingers per bunch were not appreciably influenced by the closer spacings in any of the varieties studied.

ACKNOWLEDGEMENTS

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EFFECT OF CULTIVATION WITH ALTERNATIVE FORMS OF TILLAGE IMPLEMENTS WITH AND WITHOUT INTER-CULTURE ON THE YIELD OF *BAJRA* (*PENNISETUM TYPHOIDES* STAPF. AND HUBB.) UNDER RAINFED CONDITIONS

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Received: October 26, 1960

Bajra or pearl millet is one of the important food crops of India. The total area under millets is about 50 per cent of the *kharif* cereals. According to a recent estimate *bajra* occupies 27·9 m. acres of land in this country. The crop thrives well on sandy soils and is largely grown in central, southern and western India. Its cultivation is limited to areas of low and well distributed rainfall. *Bajra* has been known to grow on as little as nine inches of rain.

Millets, though occupying a large area under foodgrain crops, have received less aid from science than other crops. The reason, for this poor man's food not receiving proper attention, may be attributed to the precarious condition of soil and climate under which it is grown. The other, comparatively less important, reasons could be the difficulty in breeding and low commercial value of *bajra* besides preoccupation of scientists with more valuable crops.

Having the above background in view an investigation, was started in Todapur Block of the farm attached to Indian Agricultural Research Institute, New Delhi under rainfed condition. The results obtained from the field experiment are reported here.

EXPERIMENTAL PROCEDURE

The study was started in 1957 on a sandy loam soil in Delhi, and observations were continued on the same plot till the end of 1960. Delhi, on average, receives about 25 inches of rainfall in a year. July and August are the wettest months, each getting eight to nine inches of rain, followed by about four to five inches during September.

The experiment was laid out in a split-plot design.

Treatments

(a) Main plot (cultivation)
- C_1 Cultivation to a depth of 10 inches with tractor implements.
- C_2 Bullock cultivation with ' Victory ' *cum* ' Country ' ploughs to a depth of 5 inches.
- C_3 Bullock-cultivation with spring-tined harrow to a depth of 3 inches.

(b) Subplot (interculture)
- X Interculture by bullock-hoe in the standing crop.
- Y Weeding by hand-hoe in the standing crop.
- Z Control (no weeding).

About five tons of ' compost ' was added each season uniformly to all the plots. *Bajra* after *bajra* was grown every year without any intervening crop during *rabi*.

On an average three cultivations were given to C_1 and five to each of the C_2 and C_3 treatments.

The experiment was conducted on a well-drained soil of average fertility with a pH of 7.

The quality of soil fabric prepared with various treatments may be gauged from Table I.

TABLE I. EFFECT OF CULTIVATION ON THE SIZE DISTRIBUTION OF WATER STABLE AGGREGATES AND PORE-SPACE

Treatments	3 mm.	2 mm.	Percentage 1 mm.	0·5 mm.	72 mesh	120 mesh	Pore-space
C_1 0–6″	3·8500	0·5002	0·5802	0·5498	1·8140	12·0160	41·3
6–12″	2·1980	0·4202	0·9200	1·2702	7·2198	11·5200	42·3
C_2 0–6″	1·4002	0·4100	0·7200	1·1730	5·3930	12·9130	41·0
6–12″	1·9600	0·5750	2·2702	2·9900	15·0208	10·1202	40·7
C_3 0–6″	4·6002	1·4602	1·4500	1·4802	5·5504	12·7504	41·4
6–12″	1·8500	0·4206	2·5502	3·9500	12·6006	11·6302	40·9

It appears from Table I that ' tilth ' is almost the same under various cultivation treatments with a tendency to be slightly better under C_1.

RESULTS

In order to have an idea of the work, for the period as a whole, the data relating to different years were pooled and analysed serially. The results obtained are summarised in Table II.

TABLE II. EFFECT OF TILLAGE ON THE YIELD OF INDIVIDUAL YEARS AS WELL AS AVERAGE YIELD FOR 1957-59 (MD. PER ACRE)

Treatments	Years 1957	1958	1959	Average
C_1 Tractor ploughing followed by grubling and discing	8·91	4·92	2·94	5·59
C_2 Victory-*cum*-country	7·81	3·48	2·04	4·41
C_3 Surface cultivation—spring land	7·74	3·19	2·08	4·33
'F' Test	Sig. 5%	Sig. 1%	Sig. 1%	Sig. 1%
S m±	0·39	0·33	0·21	0·19
C.D. 5%	0·90	0·96	0·61	0·55

It appears from Table II that deep ploughing has helped significantly to increase the yield of grain. The difference between the two shallow depths has not been found to be significant under the serial analysis. In the dry-farm crops the conservation of moisture appears to be a dominant factor in raising yields. The poor yields in the last two years may be attributed to the adverse effect of weather which resulted in the lodging of crop and washing of flowers because of heavy and untimely rains.

The yield obtained with 'Interculture' treatments is given below (Table III).

TABLE III. EFFECT OF INTERCULTURE ON THE YIELD OF GRAIN (MD. PER ACRE)

Treatments	Years			Average
	1957	1958	1959	
X—Interculture by bullock-hoe	7·82	4·09	3·11	5·00
Y—Weeding with hand-hoe	9·01	4·82	6·14	6·66
Z—Control (no weeding)	7·65	2·71	2·46	4·27
'F' Test	Sig. 1%	Sig. 1%	Sig. 1%	Sig. 1%
S.Em.±	0·39	0·33	0·21	0·19
C.D. 5%	0·90	0·96	0·61	0·55

The results obtained with the intercultivation treatments are interesting. Weeding with hand-hoe has given significantly higher yield over the other two treatments. The interculture with bullock-hoe, however, is significantly better than control. It seems that the weeds left near the plants were not completely removed by bullock-hoeing and hence the yield was depressed. The depth of cultivation in this regard is not so important as the complete removal of weeds. The weeds compete seriously with the crop for moisture, sunlight and plant food.

The interactions between the cultivation and interculture treatments were not found to be significant.

DISCUSSION

The most important finding of the experiment is that deep ploughing, for the first time in these studies with various crops, has shown significantly higher yield than shallow ploughing. This may, perhaps, be due to greater intake and storage of water which increases the production potential of crops under rainfed condition. Similar views of appreciable increase in moisture storage and thereby the crop yield in semi-arid regions, have been expressed by many workers. To quote a few the names of King (1892), Grandean (1894), Kuran (1948), Ivanov (1950), Evans (1956) and Grisson (1956) might be mentioned.

The results of subplot treatments are also interesting. They have clearly shown the impact of weeds in reducing crop yield. Russell and Keen (1940) have pointed

out after six years' of experimentation that primary function of tillage is weed control. Cates and Cox (1912) believed that the principal value of cultivation was in killing weeds. Parker and Jenny (1945) observed that frequent tillage was necessary for weed control in row crops. The weeds around the plants were meticulously removed with hand weeding and not by bullock-hoeing. This has reflected on the higher yield obtained under the former treatment.

SUMMARY AND CONCLUSION

To sum up, it may be stated that under rainfed condition the production potential can be considerably increased through deep ploughing. The first and foremost requirement of crop is water which, if properly conserved, would help boost the yield considerably.

In the same way the extent to which weeds have been removed from the crop will largely determine the quantum of yield under rainfed condition. The case in point has clearly demonstrated the effect of complete removal of weeds by hand-weeding on the yield of *bajra*.

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COMPARATIVE STUDIES ON SOME *ALTERNARIA* SPECIES OCCURRING ON SOLANACEOUS HOSTS

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Received: March 28, 1960

Alternaria leafspots are of common occurrence on several solanaceous plants, which are extensively cultivated in India. At least four known species of the genus, viz., *A. longipes* (Ell. and Ev.) Mason, *A. solani* (Ell. and Mart.) Jones and Grout, *A. tomato* Cke., and *A. violae* Galloway and Dorsett (and some unidentified species) have so far been reported on solanaceous plants in this country. Recently, Rangaswami and Sambandam (1960 a, b) reported occurrence of a new species of *Alternaria*, *A. melongenae* Rang. and Samb. on brinjal (eggplant) and chilli, and the variations of spore size of the fungus due to its substratum. Among the various species so far reported on solanaceous hosts, *A. solani* appears to be by far the most common species occurring on potato and tomato (Butler, 1903; Mitra, 1925; Narasimhan, 1931), chilli (Subramanian, 1954) and *Datura stramonium* L. (Bal, 1919). No detailed investigation seems to have been carried out in India so far to compare the various species of *Alternaria* on solanaceous hosts.

In the present study four species of *Alternaria*, viz., *A. tenuis* Nees., *A. crassa* (Sacc.) Rands, *A. solani* and *A. melongenae* from different sources were studied in detail to compare their pathogenicity and host range and also their morphological, cultural and physiological properties and the results are reported here.

MATERIAL AND METHODS

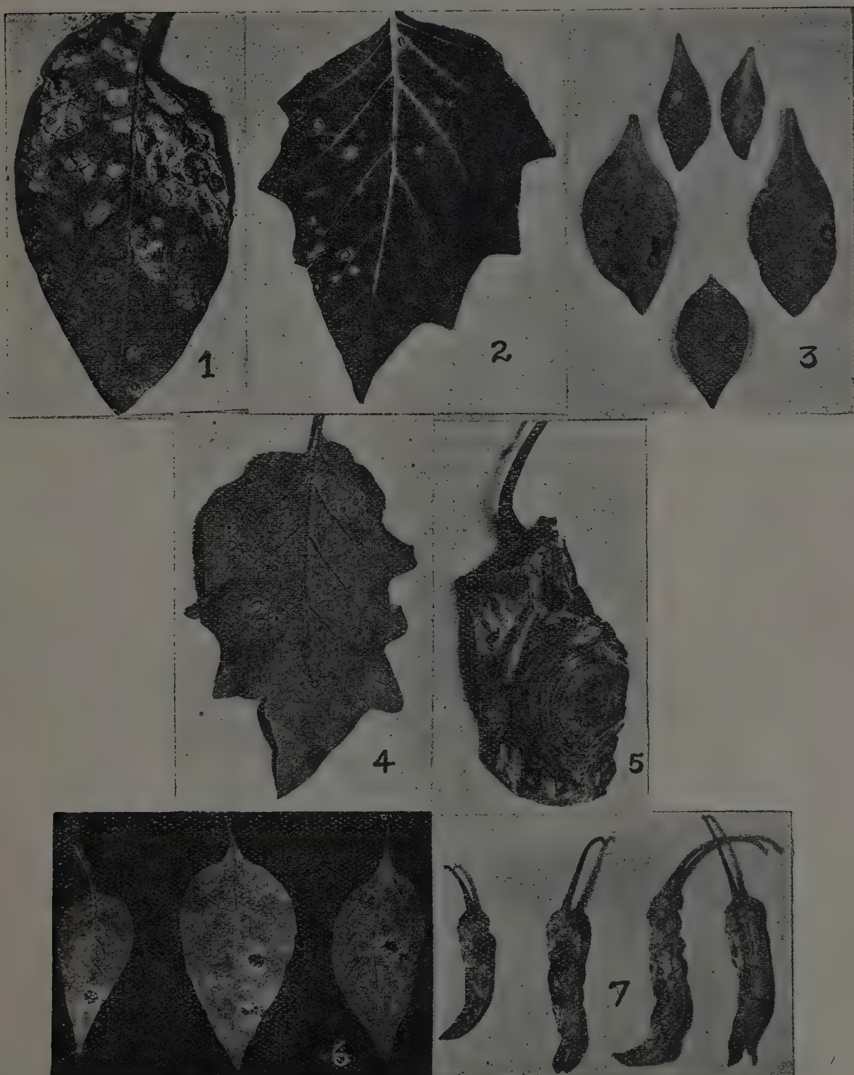
The fungal isolates (Plate I) selected for this study were:

1. *A. crassa* causing leafspot of *Datura fastuosa* var. *alba* C.B. Clarke.,
2. *A. tenuis* causing leafspot of *D. fastuosa* L.,
3. *A. tenuis* causing leafspot of *Capsicum annuum* L.,
4. *A. tenuis* causing leafspot of *Petunia hybrida* Vilm.,
5. *A. melongenae* causing leafspot of *Solanum melongena* L.,
6. *A. solani* causing early blight of *S. tuberosum* L.,
7. *A. melongenae* causing fruit scab of *S. melongena*., and
8. *A. melongenae* causing fruit rot of *C. annuum.*

A. solani, on potato, was obtained from the Nilgiri hills and all the other specimens were collected locally. The fungus from each of the infected material was isolated by the tissue culture technique and purified by the single hyphal tip method. The stock cultures of the isolates were maintained on potato dextrose agar slants.

Pathogenicity test: The pathogenicity of the fungi was tested on healthy host plants, raised under controlled conditions in the Pot Culture House. Inoculations were made on young leaves, after surface sterilizing with mercuric chloride solution

PLATE I



ALTERNARIA ON SOLANACEOUS HOSTS

1. *A. crassa* ON *Datura fastuosa* VAR. *alba;* 2. *A. tenuis* ON *D. fastuosa;* 3. *A. tenuis* ON *Petunia hybrida;* 4. *A. melongenae* ON BRINJAL LEAF; 5. *A. melongenae* ON BRINJAL FRUIT; 6. *A. tenuis* ON CHILLI LEAF; 7. *A. melongenae* ON CHILLI FRUIT

(1:1000) and washing with sterile water. Seven-day old culture of the fungus, grown on potato dextrose agar slants, was transferred to the leaf surface. Small bits of the mycelium were used as inocula and a bit of wet, sterile cotton wool was placed over the inocula, to keep them moist. The leaf was then covered with alkathene bags or cages and high humidity maintained inside by frequent sprayings. Whenever inoculations were successful, the pathogen was reisolated from the infected area, and the isolate compared and verified with the original inoculum.

For inoculation studies on the fruits (Plate II), both unripe and ripe fruits were selected. They were inoculated with the test fungus either with or without prior wounding of the skin, following the method used by Rafay (1935). The inoculated fruits were covered with alkathene bags and high humidity was maintained as before.

Growth on agar media: The comparative growth of the fungi on various agar media was studied in the following manner: Equal quantities of agar medium were poured in 10 cm. Petri dishes and allowed to set. A 4 mm. culture disc of the fungus, cut with a sterile cork borer from the actively growing region of a week-old culture of the fungus on potato dextrose agar, was transplanted aseptically to the centre of medium in Petri dishes. On inoculation, the dishes were incubated at room temperature (28-29°C) and observations on the growth rate of the fungus, morphological as well as physiological characters like pigment production in the medium were made. The rate of growth of the fungus was obtained by measuring the diameter of the colony at periodical intervals. Triplicates were maintained for each isolate and treatment and the average growth calculated.

Growth in liquid media: Erlenmeyer flasks, 250 or 500 ml. in size, containing 50 or 100 ml., respectively, of the various liquid media, were inoculated aseptically with 4 mm. culture discs of the fungus obtained as detailed above. The flasks were incubated at room temperature for ten days. The mycelial mat was filtered through a Buchner funnel connected to a suction pump, using a filter paper of known weight, dried in a hot air oven to a constant weight and the dry weight of the mat obtained.

EXPERIMENTAL RESULTS

I. *Inoculation Studies*

(i) *Pathogenicity tests:* Seven-day-old cultures of the eight isolates of *Alternaria* were inoculated on respective hosts according to the procedure detailed under Material and Methods. Pathogenicity tests were conducted thrice during November, 1958 to January, 1959 and the results are summarised in Table I. The results on fruit inoculations of brinjal and chilli are given in Table II.

The data establish the pathogenicity of the isolates on their respective hosts. However, aggressivity of the isolates as well as the incubation period were found to differ. Table II clearly indicates that *A. melongenae* isolated from brinjal fruit scab is a wound parasite affecting only soft, ripe fruits, but not firm, unripe fruits; *A. melongenae* isolate from chilli fruit rot is capable of parasitizing ripe fruits only and that wounded ripe fruits are infected very easily, while it could infect, to some extent, the ripe fruits even without wounding.

TABLE I. PATHOGENICITY OF SIX ISOLATES OF *ALTERNARIA* ON THEIR RESPECTIVE HOSTS

Alternaria isolate from the leaves of	Number of leaves infected/ Number of leaves inoculated — Dates of inoculation 28–11–58	15–12–58	28–1–59	Average % infection	Remarks
A. crassa from *D. fastuosa* var. *alba* leaves	7/8	5/8	6/8	75	Infection symptoms within 5 days
A. tenuis from *D. fastuosa* leaves	3/8	2/8	2/8	29	Infection symptoms within 10 days
A. tenuis from *C. annuum* leaves	2/8	5/8	2/8	38	Infection symptoms within 8 days
A. melongenae from *S. melongena* leaves	2/8	4/8	1/8	29	Infection symptoms within 13 days
A. tenuis from *P. hybrida* leaves	6/8	5/8	5/8	67	Infection symptoms within 3 days
A. solani from *S. tuberosum* leaves	8/8	6/8	7/8	88	Infection symptoms within 3 days

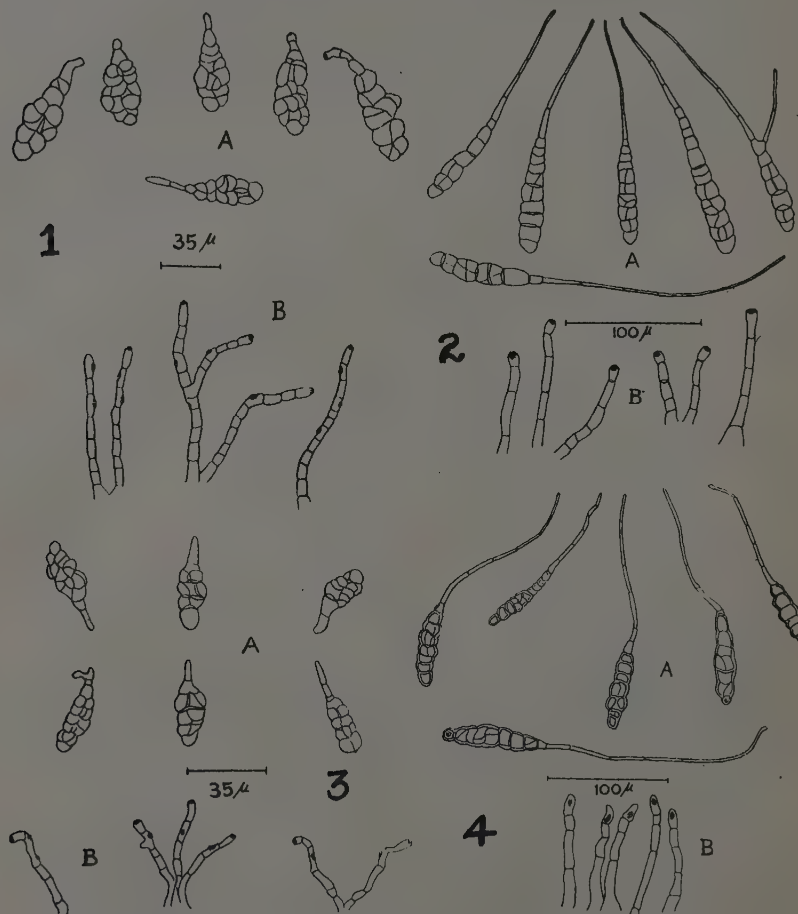
TABLE II. PATHOGENICITY OF *A. MELONGENAE* ON BRINJAL AND CHILLI FRUITS

Isolate and type of fruits inoculated	Number of fruits infected/ Number of fruits inoculated — Dates of inoculation 11–12–58	1–1–59	30–1–59	Average % infection	Remarks
A. melongenae from brinjal fruit scab					
On ripe fruits—wounded	3/8	1/8	2/8	25	Symptoms of infection in 14 days
On ripe fruits—not wounded	0/8	0/8	0/8	0	
On unripe fruits—wounded	0/8	0/8	0/8	0	
On unripe fruits—not wounded	0/8	0/8	0/8	0	
A. melongenae from chilli fruit rot					
On ripe fruits—wounded	13/16	14/16	14/16	85	Infection symptoms in 6 days
On ripe fruits—unwounded	7/16	8/16	7/16	46	Infection symptoms in 10 days
On unripe fruits—wounded	1/16	0/16	1/16	2	Infection symptoms in 12 days
On unripe fruits—unwounded	0/16	0/16	0/16	0	No infection

(ii) *Cross inoculation studies:* With a view to study the cross infectivity and interrelationship of the eight *Alternaria* isolates, they were inoculated on all the eight hosts. These inoculations were replicated three times during November, 1958 to January, 1959. The results are summarised in Table III.

The chief findings are: (a) that *A. solani* from potato could infect the leaves of all the test plants and also chilli and brinjal fruits; (b) *A. crassa* from *D. fastuosa* var. *alba* could infect, besides its original host, *D. fastuosa*, and potato and chilli leaves

PLATE II



CONIDIA (A) AND CONIDIOPHORES (B) OF FOUR SPECIES OF *Alternaria*
1. *A. melongenae;* 2. *A. solani;* 3. *A. tenuis;* 4. *A. crassa*

TABLE III. CROSS INOCULATION OF EIGHT ISOLATES OF *ALTERNARIA* FROM SOLANACEOUS HOSTS

Host	Number of leaves or fruits infected/ Number of leaves or fruits inoculated							
	A. crassa from *D. fastuosa* var. *alba*	*A. tenuis* from *D. fastuosa*	*A. tenuis* from chilli leaf	*A. melongenae* from brinjal leaf	*A. tenuis* from Petunia leaf	*A. solani* from potato leaf	*A. melongenae* from brinjal fruit	*A. melongenae* from chilli fruit
Datura fastuosa var. *alba* leaf	19/24	4/24	3/24	0/24	7/24	13/24	0/24	0/24
D. fastuosa leaf	11/24	6/24	4/24	0/24	7/24	10/24	0/24	0/24
Chilli leaf	0/24	9/24	10/24	13/24	10/24	20/24	13/24	11/24
Brinjal leaf	0/24	3/24	5/24	8/24	18/24	17/24	7/24	5/24
Petunia hybrida leaf	0/24	7/24	3/24	5/24	18/24	9/24	0/24	0/24
Potato leaf	8/24	5/24	2/24	0/24	8/24	21/24	0/24	0/24
Brinjal fruit—ripe wounded	0/9	0/9	0/9	5/9	0/9	4/9	6/12	5/9
Chilli fruit—ripe wounded	0/24	0/24	2/24	22/24	0/24	21/24	22/24	20/24

only; (c) *A. tenuis* from *D. fastuosa*, chilli leaf and *P. hybrida* had almost the same cross infectivity, except for some minor differences; and (d) *A. melongenae* isolates from brinjal leaf, brinjal fruit and chilli fruit were identical in their host specificity, being infective on the leaves and fruits of brinjal and chilli.

The symptoms produced by *A. solani* on *D. fastuosa* var. *alba* and the symptoms produced by *A. crassa* from *D. fastuosa* var. *alba* on potato, *D. fastuosa* and *D. fastuosa* var. *alba* were of the typical ' target-board ' appearance. In all cases water-soaked spots appeared around the place where the inoculum was placed, followed by necrosis of the affected tissues. The fungi were reisolated from the infected plants and were found to be invariably identical with the respective original cultures used for inoculation.

(iii) *Host range:* In order to ascertain the host range of eight isolates, they were inoculated on the leaves of 19 different host plants, 14 of which were solanaceous crop plants, ornamentals or weeds and the remaining five non-solanaceous weeds belonging to different families and of common occurrence in this tract. In all, three series of inoculations were made during December, 1958 to March, 1959. The results are summarised in Table IV. Adopting Neergard's (1945) method, the percentages of infections are represented in Fig. 1.

The results show that all the isolates were capable of infecting tomato and *Solanum nigrum*, while none could infect any of the non-solanaceous species and *Cestrum diurnum* and *Physalis minima* of Solanaceae; that *A. solani* from potato had the widest host range infecting 11 out of the 14 solanaceous species and was also more virulent than the other isolates; and that *A. tenuis* from *D. fastuosa*, chilli leaves and *P. hybrida* had the similar host ranges, infecting the same 11 out of 14 solanaceous species.

TABLE IV. HOST RANGE OF EIGHT ISOLATES OF *ALTERNARIA*

Hosts	Number of leaves infected/Number of leaves inoculated							
	A. crassa from *D. fastuosa* var. *alba* leaf	*A. tenuis* from *D. fastuosa* leaf	*A. tenuis* from chilli leaf	*A. melongenae* from brinjal leaf	*A. tenuis* from *Petunia* leaf	*A. solani* from potato leaf	*A. melongenae* from brinjal fruit	*A. melongenae* from chilli fruit
SOLANACEOUS								
Capsicum annuum L.	0/24	7/24	11/24	10/24	13/24	17/24	14/24	11/24
Cestrum diurnum L.	0/24	0/24	0/24	0/24	0/24	0/48	0/24	0/24
Datura fastuosa L.	12/24	5/24	5/24	0/24	8/24	7/24	0/24	0/24
D. fastuosa var. *alba*	18/24	2/24	3/24	0/24	5/24	10/24	0/24	0/24
Lycopersicum esculentum Mill.	7/24	4/24	3/24	6/24	9/24	24/24	7/24	6/24
Nicotiana tabacum L.	0/4	3/12	2/12	0/24	10/15	3/12	0/24	0/24
Petunia hybrida Vilm.	0/24	3/12	2/12	0/24	19/24	6/24	0/24	0/24
Physalis minima L.	0/24	0/24	0/24	0/24	0/24	0/36	0/24	0/24
Solanum melongena L.	0/24	2/24	3/24	7/24	14/24	16/24	5/24	8/24
S. nigrum L.	10/24	8/24	7/24	9/24	17/24	24/24	9/24	10/24
S. torvum L.	0/4	1/12	2/12	0/24	3/12	7/12	0/24	0/24
S. trilobatum L.	9/24	4/24	3/24	0/24	7/24	19/24	0/24	0/24
S. tuberosum L.	9/24	4/24	3/24	0/24	7/24	19/24	0/24	0/24
S. xanthocarpum Schrad. and Wendll.	0/24	0/12	0/12	0/24	0/12	6/12	0/24	0/24
NON-SOLANACEOUS								
Aristolochia bracteata Rtz. (Aristolochiaceae)	0/24	0/24	0/24	0/24	0/24	0/24	0/24	0/24
Croton sparsiflorus Mor. (Euphorbiaceae)	0/24	0/24	0/24	0/24	0/24	0/24	0/24	0/24
Eclipta alba Harsk (Compositae)	0/24	0/24	0/24	0/24	0/24	0/24	0/24	0/24
Gomphrena decumbens Jacq. (Amarantaceae)	0/24	0/24	0/24	0/24	0/24	0/24	0/24	0/24
Leucas aspera Spreng (Labiatae)	0/24	0/24	0/24	0/24	0/24	0/24	0/24	0/24

A. crassa from *D. fastuosa* var. *alba* could infect with medium virulence, only 6 out of 19 species. All the three *A. melongenae* isolates had limited, but identical, host ranges, affecting only four out of the 19 species tested.

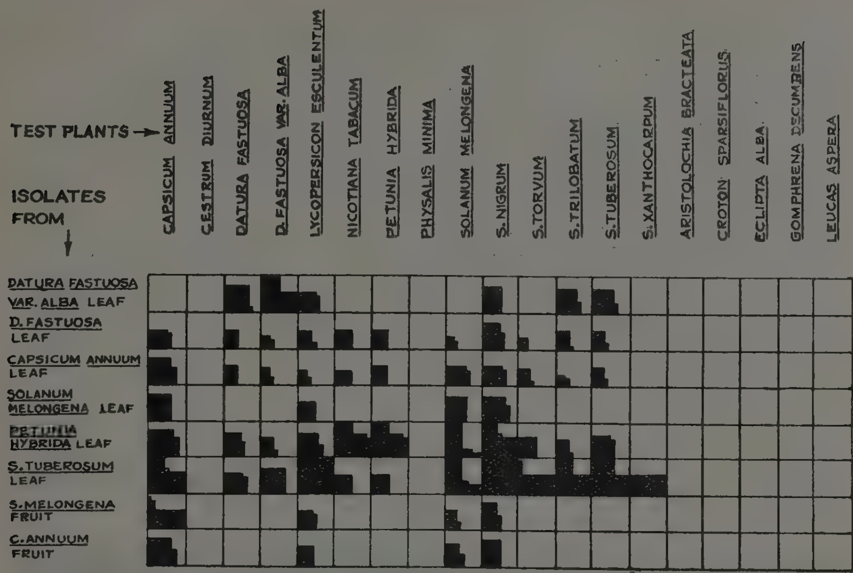


FIG. 1. HOST RANGE OF EIGHT *Alternaria* ISOLATES AS DETERMINED BY ARTIFICIAL INOCULATION. (COMPLETE DARK SQUARE REPRESENTS CENT PER CENT INFECTION)

II. *Physiological Studies*

According to Neergard (1945) temperature requirements of *Alternaria* spp. are of diagnostic importance in differentiating physiological races within the individual species or variety. Other criteria of lesser taxonomic importance mentioned by him are chromogenesis and crystalogenesis in the culture media. Studies on the physiology of the *Alternaria* isolates were therefore undertaken and the results are reported hereunder.

(i) *Influence of temperature on growth:* To study the influence of temperature on growth, all the eight isolates were grown in Petri dishes containing potato dextrose agar or in Erlenmeyer flasks with potato dextrose broth and incubated at 8°, 15°, 22°, 29° and 34°C. There were three replications in each treatment. The diameter of the colony on agar media after seven days and the dry weight of mycelial mat in liquid media after ten days were determined. The results obtained revealed, that all the isolates grew best both in agar and liquid media at 29°C. Growth was fairly good at 22°C, while it was poor at 15° and 34°C. Eevn at 8°C, all the isolates showed some growth, though very meagre.

A. solani from potato leaf formed a reddish orange soluble pigment while the three isolates of *A. melongenae* formed a deep purple pigment in potato dextrose agar. Very low temperatures inhibited pigment production, while maximum production was observed at optimal temperature for the growth of the fungi; there was no pigment

production at 8°C, maximum production at 29°C, and limited production at 34°, 22° and 15°C.

(ii) *Influence of H-ion concentration on growth:* The influence of H-ion concentration of the media on the growth of fungi was studied using Richard's medium.

The results showed that all the isolates are capable of growing under a wide range of H-ion concentration except for some individual variations. The opitimum pH for *A. solani* from potato seemed to be around 6, for *A. crassa* around 7, and for *A. tenuis* and *A. melongenae* between 6 and 7.

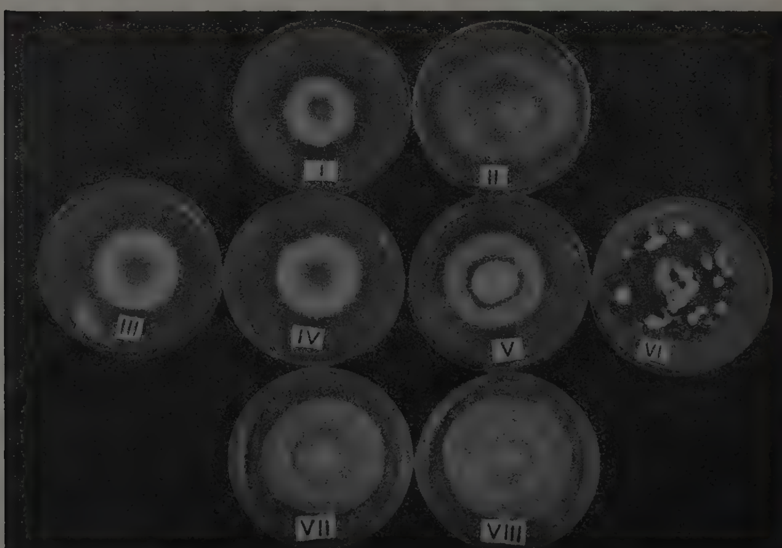
The depth of the pigment produced was found to depend on the pH of the substratum. In the case of *A. solani* the pigment was pink at pH 5 and 6, orange red at pH 7 and 8, and carmine at pH 9 and 10; whereas with *A. melongenae* the pigment was light purple at pH 5 and 6, deep purple at pH 7 and 8, and very deep purple at pH 9 and 10.

(iii) *Growth on artificial media:*

A. Agar Media.—With the object of finding out the best medium for growing the isolates, six agar media were tested in Petri dishes.

There was fair growth of the isolates in all the media, but there was maximum growth in potato dextrose agar. Among the complex media, nutrient agar was least

Plate III



Comparative growth of *Alternaria* spp. in Richard's agar

I. *A. crassa* from *Datura fastuosa* var. *alba* leaf; II. *A. solani* from potato leaf; III. *A. tenuis* from *D. fastuosa* leaf; IV. *A. tenuis* from chilli leaf; V. *A. melongenae* from brinjal leaf; VI. *A. tenuis* from *Petunia Hybrid A.* leaf; VII. *A. melongenae* from brinjal fruit; VIII. *A. melongenae* from chilli fruit

favourable and of the synthetic media, Richard's agar (Plate II) was more favourable than Czapek's agar. *A. solani* and *A. melongenae* isolates produced soluble pigments in all the media, the colour ranging from orange to red in the former case and light to deep purple in the latter case. In potato dextrose, oatmeal, and Czapek's and Richard's agar media there was greater diffusion of the pigment in the substrate than in the case of nutrient agar and yeast extract glucose agar, where the pigment was seen just around the colony. None of the isolates produced crystals in any of the culture media tested.

B. LIQUID MEDIA.—Six liquid media were tested for the growth of the isolates following the procedure described elsewhere. As in the case of agar media, potato dextrose broth was the most favourable medium and nutrient broth was least favourable among the complex media. Growth was moderate in brinjal leaf broth and yeast extract glucose broth. Of the two synthetic media, Richard's solution was better than Ken Knight's solution. Pigmentation could be observed in potato dextrose broth, Richard's solution and Ken Knight's solution. *A. solani* produced orange pigment, while in the *A. melongenae* isolates the pigment was light purple coloured.

(iv) *Utilization of nitrogen sources:* To find out the capacity of *Alternaria* isolates to utilize various nitrogen sources they were grown in Richard's agar containing different nitrogen sources. The data showed that urea was the best nitrogen source for the growth of the isolates, glutamic acid was least favourable, while growth was moderate in asparagine, creatine and tyrosine. There appeared to be no individual preferences for any of the nitrogen sources by any of the isolates.

(v) *Utilization of carbon sources:* With a view to study the capacity of the *Alternaria* isolates to utilize various carbon sources, they were grown in Richard's agar containing different carbon sources. Starch was found to be most suited for the growth of all the eight isolates. *A. crassa* grew well in levulose also, *A. tenuis* in lactose and *A. melongenae* well in maltose.

(vi) *Carbon/Nitrogen ratio and growth:* With a view to find out the influence of the carbon/nitrogen ratio of the medium on the growth of the isolates, Richard's agar medium containing various concentrations of starch and urea was prepared and the fungi inoculated.

All the eight isolates grew best in the C/N ratio of 30 gm. of starch/2 gm. of urea per litre of the medium. In the lower ranges of starch, i.e., 5 to 20 gm./litre very poor aerial mycelium was obtained on the agar media.

DISCUSSION

The cross inoculation and host range studies with the eight isolates obtained from different hosts have brought out the interrelationships of the hosts and fungi. *A. crassa* is able to infect leaves of *D. fastuosa*, *D. fastuosa* var. *alba*, *S. nigrum* and *S. trilobatum*. *A. tenuis* isolates from *D. fastuosa*, *C. annuum and P. hybrida* could infect each other and also *D. fastuosa* var. *alba*, *N. tabacum*, *L. esculentum*, *S. melongena*, *S. nigrum*, *S. torvum* and *S. trilobatum* on artificial inoculation. The three isolates of *A. melongenae* were found to have a limited host range, infecting only *L. esculentum* and *S. nigrum*, besides the natural hosts. *A. solani* from potato is infective on the leaves and fruits of chilli, leaves and fruits of brinjal and leaves of *D. fastuosa*, *D.*

fastuosa var. *alba*, *L. esculentum*, *N. tabacum*, *P. hybrida*, *S. nigrum*, *S. torvum*, *S. trilobatum*, and *S. xanthocarpum*, indicating thereby the wide host range of the fungus. Of the hosts studied, a good number of them are common weeds in the cultivated fields and uncultivated wastelands of this locality. These plants form an important ground for perpetuation and spread of the pathogens. Also some of the perennials like *S. torvum* and *S. trilobatum* might play greater role in the spread of the disease than the annuals.

When the eight isolates of *Alternaria* from various sources were compared for their relative growth on six agar media, *A. crassa*, *A. tenuis* and *A. solani* grew comparatively faster than *A. melongenae*. All the isolates of *Alternaria* were found to grow best at 29°C. This finding seems to be in agreement with earlier reports on *A. tenuis* and *A. solani* (Rands, 1917; Bonde, 1929; Kreutzer and Durrel, 1933; Nightingale and Ramsey, 1936; Neergard, 1945).

For *A. crassa* the optimum pH for growth was 7, both in agar and liquid media, for *A. tenuis* and *A. melongenae* about pH 6·5 and for *A. solani* pH 6. There appears to be no previous report in this respect on *A. crassa* and *A. tenuis*, while the present finding for *A. solani* is in very close agreement with that of Ramsey (1935).

In the studies on the utilization of the various carbon and nitrogen sources by the fungal isolates, starch was found to be the best carbon source and urea the best nitrogen source for all the isolates. Similar results were obtained for *A. ricini* by Pawar and Patel (1957). There seems to be little information available in the literature on C/N ratio and growth of *Alternaria*. In the present studies it was observed that the ratio of nitrogen and carbon had great influence on growth; the best growth was obtained with 3 gm. of starch/0·2 gm. of urea per 1 litre of medium.

The information obtained on the three isolates of *A. melongenae* from brinjal leaf, brinjal fruit and chilli fruit, clearly indicated that they were identical in (1) pathogenicity, (2) cultural characters, and (3) nutritional and physiological properties. Observations made on the chromogenesis of the fungal isolates under various cultural and physiological conditions, have clearly brought out that *A. solani* and *A. melongenae* were highly chromogenic in both complex and synthetic media. The colour of the pigment produced by *A. solani* was of different shades of red, whereas that produced by *A. melongenae* was of different shades of purple. The other chromogenic species of *Alternaria*, viz., *A. anagallidis* Raabe, *A. linicola* Neerg. and *A. porri* (Ell.) Neerg. are all known to produce only red pigments of different shades (Neergard, 1945). There was maximum chromogenesis of *A. solani* and *A. melongenae* in potato dextrose agar and potato dextrose broth. The amount of pigment produced by the two fungi seem to vary with the pH of substratum, the incubation temperature and age of the isolate. Conditions which favour good growth of the colony, viz., optimum pH level, optimum incubation temperature and freshness of the isolate, also seem to favour the production of large amounts of the pigments. Similar results have been reported by Neergard (1945) for *A. solani*. According to Bonde (1929), the colour of the pigment produced by *A. solani* was an indicator of the pH of the substratum and that in a basic medium the pigment was deep red or carmine in colour while at lower pH levels the colour was progressively lighter. In the present studies the pigment of *A. melongenae* was light purple at pH 5 and 6, purple in pH 7 and 8 and deep purple at pH 9 and 10.

The observations made on the sporulation of the fungal isolates under different conditions revealed that when isolated fresh from host plants, all of them, except *A. solani*, sporulated fairly well in different media. *A. tenuis* and *A. crassa* were found to lose their capacity for sporulation after subculturing in artificial media, whereas *A. melongenae* sporulated profusely even after repeated subculturing for more than 12 months. Among the four chromogenic species of *Alternaria* known so far, *A. solani*, *A. linicola* and *A. anagallidis* do not sporulate in culture, while *A. porri* may produce a very limited number of spores in cultures (Neergard, 1945). In the present studies *A. melongenae* was found to sporulate profusely in all the culture media tested.

SUMMARY

Alternaria crassa (Sacc.) Rands, *A. tenuis* Nees., *A. solani* (Ell. and Mart.) Jones and Grout and *A. melongenae* Rang. and Samb., were compared for their host range and some cultural and physiological properties.

A. crassa, isolated from leaves of *Datura fastuosa* var. *alba*, could infect, besides its natural host, *D. fastuosa*, *Lycopersicum esculentum*, *Solanum tuberosum* and *S. nigrum*, the first two hosts being reported for the first time. *A. tenuis* isolates from leaves of *D. fastuosa*, *Capsicum annuum* and *Petunia hybrida* were found not only to cross infect each other's host, but also to infect *D. fastuosa* var. *alba*, *L. esculentum*, *Nicotiana tabacum*, *S. melongena*, *S. nigrum*, *S. torvum*, *S. trilobatum* and *S. tuberosum;* among these the new hosts are *D. fastuosa* var. *alba*, *S. melongena*, *S. torvum* and *S. trilobatum*. *A. solani* from potato was found to pass on to *C. annuum*, *L. esculentum*, *N. tabacum*, *S. melongena*, *S. nigrum*, *S. tuberosum*, *D. fastuosa*, *D. fastuosa* var. *alba*, *P. hybrida*, *S. torvum*, *S. trilobatum* and *S. xanthocarpum*; of these, the last six hosts are first reports. *A. melongenae* was rather specific in its host range, infecting only the leaves and fruits of *S. melongena* and *C. annuum*, and leaves of *S. nigrum* and *L. esculentum*.

All the eight isolates were found to grow well at an incubation temperature of 29°C and in the pH range of 6 to 7. They utilized starch as the best carbon source and urea as the best nitrogen source. The best growth was obtained with all the isolates with 30 gm. of starch and 2 gm. of urea per litre of medium.

A. melongenae isolates were highly chromogenic in both complex and synthetic agar as well as liquid media, producing light purple pigment at pH 5 and 6, purple at pH 7 and 8, and deep purple at pH 9 and 10.

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EFFECTS OF FERTILIZERS ON THE YIELDS OF PADDY AND BERSEEM IN PADDY-BERSEEM ROTATION

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In northern India, berseem (*Trifolium alexandrium*) is gaining popularity as a leguminous forage crop in rotation with paddy, wherever irrigation facilities are available. This is due to the highly nutritious and palatable nature of this fodder. Besides, it yields much higher than other winter fodder crops, viz., *methra* (*Trigonella foenum-graecum*), *senji* (*Melilotus parviflora*) or *shaftal* (*Trifolium resupinatum*) and supplies green succulent fodder in a number of cuttings. Being rich in protein, phosphate and calcium it maintains the cattle in good condition which is otherwise fed on poor paddy straw rations.

With regard to the manurial requirements of paddy crop, nitrogen in the form of ammonium sulphate has generally given a substantial response as reported by Sethi *et al.* (1940), Dave (1947), Grist (1952), Vachhani (1952), Mukherjee (1955), and Gupta and Relwani (1957). Yates *et al.* (1953) have reported the average standardised response of 280 lb. per acre in India for 20 lb. N dose. Vladimir (1951) pointed out that although ammonium sulphate appeared to be the most effective for lowland rice, the application of one or two plant nutrients specially in large doses might cause reduction in yield of crops by accentuating an existing condition of plant nutrient unbalance in the soil. Increased yields of paddy have been reported with application of phosphate by Clark (1930), Haigh *et al.* (1933), Crowther *et al.* (1937), Sethi *et al.* (1940), Kadam (1945) and Dave (1947). Ghose *et al.* (1956) from recent experimental evidence conclude that rice yields could be increased by supplementing ammonium sulphate with a dose of superphosphate in a large variety of soils in India. The average response obtained on cultivators' fields in T.C.M. trials conducted in 1953-54 varied from 217 lb. of paddy for 20 lb. P_2O_5 to 307 lb. for 40 lb. P_2O_5 levels.

Effect of phosphate in increasing legume yields has generally been conspicuous (Truesdell, 1917; Erdman and Wilkins, 1928; West, 1936; Sen and Bains, 1954; Sunder Rao and Ghosh, 1954; Daljit Singh *et al.*, 1957). Additional nitrogen dose applied in combination with phosphate in the earlier stages of the crop has benefited leguminous crops by providing a vigorous start. Sen and Bains (1951) and Chandnani (1955) have recorded higher yields of berseem with nitrogen and phosphate than with phosphate alone.

The role of fertilizers in legume-cereal rotations has been reported by numerous workers. Thorne (1924), Sears *et al.* (1933) and Passore (1939) stated that phosphatic fertilizers increased the yields of legume crops to which they were applied as well as of the subsequent non-legumes in the rotation. Parr and Bose (1944) not only obtained increases of 100-300 per cent in the yield of berseem by manuring with phosphate but

also higher yields of wheat in the rotation over unfertilized berseem. Parr and Bose (1947), Parr and Sen (1948), Desai *et al.* (1953), and Khan *et al.* (1954) have further confirmed that phosphate manuring of berseem not only improved the quality and yield of berseem but also improved the soil fertility which was reflected in the higher yields of succeeding cereal crops. Tisdale and Nelson (1956), citing the work of Stanford and Pierre from Iowa on fertilizing different crops in a crop rotation Corn-Oats-Alfalfa-Brome-Alfalfa-Brome, stated that application of 240 lb. of P_2O_5 on oats gave the highest yield of all crops regardless of where the other rates were applied. They, therefore, observed that as higher rates of fertilizers were used and soil fertility increased, the problem of where the fertilizer should be applied became less important.

The experimental evidence thus shows that phosphatic fertilization plays a vital role in the legume-cereal rotation in building up soil fertility. However, scant information is available with regard to effect of fertilizers in paddy-berseem rotation. Therefore, the present investigations were carried out to formulate effective and economic fertilizer practice with this type of rotation.

MATERIAL AND METHODS

The experiment was started in *kharif* 1948. The layout consisted of randomised block with four replications having a net plot size of 51 feet × 10 feet. Both the crops were grown under irrigated conditions. The experiment was closed in 1952 after taking the berseem crop. The soil is an old Jamuna alluvium known as 'bhangar' having the following mechanical and chemical composition (Table I).

TABLE I. MECHANICAL AND CHEMICAL COMPOSITION OF SOIL (PER CENT ON OVEN DRY BASIS)

Mechanical analysis			Chemical analysis		
Ingredient	Depth of sampling (inches) 0–6	6–12	Ingredient	Depth of sampling (inches) 0–6	6–12
Sand	57·88	49·04	Total nitrogen	0·076	0·060
Silt	21·04	23·78	Total P_2O_5	0·109	0·097
Clay	21·08	27·18	Available P_2O_5	30·4 lb. per acre	47·2 lb. per acre
			pH	7·9	8·0

The analyses reveal the loamy texture of the soil, low in nitrogen and medium in phosphate nutrients. The alkaline reaction is due to the presence of sodium salts in the clay complex.

The treatments tried were the combinations of the different levels of the following factors:

Levels of Nitrogen

N_0—No nitrogen
N_1—30 lb. N per acre as sulphate of ammonia
N_2—60 lb. N per acre as sulphate of ammonia

Levels of P_2O_5

P_0—No phosphate
P_1—80 lb. P_2O_5 per acre as superphosphate
P_2—160 lb. P_2O_5 per acre as superphosphate

Mode of Application

C_0—Fertilizers applied directly to paddy crop
C_1—Fertilizers applied directly to berseem crop
Thus, there were 18 treatment combinations per replication.

As the experiment was started in *kharif* 1948, the paddy crop received only direct application of fertilizers in that year. Yields of berseem in *rabi* 1948-49 were much below normal, as due to late sowing of the crop, only four instead of the usual six cuttings could be taken. Therefore, the results of *kharif* 1948 and *rabi* 1948-49 have not been discussed in this paper.

OBSERVATIONS

Weather conditions: Paddy yields in this region are largely dependent upon rainfall conditions during the monsoon months of July, August and September as the irrigation supplies from the canal are not adequate to meet the full requirements of the crop. Premature lodging of the crop due to occurrence of high winds in the month of September also results in appreciable loss of yields. Berseem green fodder production is again considerably affected by the severity of hot and dry western winds after about 10th April. Higher temperatures prevailing after this period result in drying up of the crop. Meteorological conditions for both the crops in different years are described below in Table II.

TABLE II. WEATHER CONDITIONS FROM 1949-50 TO 1951-52

Year	Rainfall in inches				Year	Mean temperature from April 11–30	
	July	August	September	Total		Maximum (°F)	Minimum (°F)
1949	9·11	3·78	3·95	16·84	1950	96·4	64·9
1950	14·57	7·95	7·84	30·36	1951	97·1	64·0
1951	1·94	6·58	3·25	11·77	1952	102·1	72·0

It may be observed that the rainfall was the highest and more equitably distributed during 1950 paddy season. In 1949 although the rainfall was optimum during the month of July, it was subnormal during the month of August which is the active growth period. Also drizzling accompanied by high winds in the end of August and early September caused premature lodging of the crop. In 1951, the monsoons failed in the month of July and water supplies from the canal were also meagre. However, normal rainfall and irrigation supply in the month of August improved the condition of the crop. Also in the month of September there were adequate supplies of irrigation to supplement the rainfall.

Regarding weather effects on the yields of berseem it may be seen that unfavourable warmer conditions in April prevailed in 1952 than in the first two years.

EXPERIMENTAL RESULTS

The yields of paddy grain and green berseem in the individual years and average yields for three years were statistically analysed for obtaining responses to different treatments.

TABLE III. EFFECT OF NITROGEN LEVELS ON PADDY YIELDS (MD. PER ACRE)

Treatments	Years			
	1949–50	1950–51	1951–52	Average
No nitrogen	15·35	28·96	22·64	22·32
30 lb. N/acre	14·65	28·60	22·94	22·06
60 lb. N/acre	15·57	29·99	26·59	24·05
'F' test	Not sig.	Not sig.	Sig. at 1%	Not sig.
S.Em	±1·081	±0·897	±1·05	±0·63
C.D. at 5%	..	..	2·98	..
C.D. at 1%	..	..	3·98	..

Nitrogen effects (Table III) were not significant in the first two years but in the last year, 60 lb. N dose was significantly superior to both 30 lb. N and control. The consolidated results show that 60 lb. N dose produced 1·73 and 1·99 md. more paddy than control and 30 lb. N dose, respectively, but these differences

TABLE IV. EFFECT OF P_2O_5 LEVELS ON PADDY YIELDS (MD. PER ACRE)

Treatments	Years			
	1949–50	1950–51	1951–52	Average
No phosphate	14·62	29·92	23·87	22·80
80 lb. P_2O_5/acre	16·51	29·77	23·37	23·22
160 lb. ,, ,,	14·44	27·86	24·93	22·41
'F' test	Not sig.	Not sig.	Not sig.	Not sig.
S.Em	±1·081	±0·897	±1·05	±0·63

were statistically not significant. It was found that phosphate effects were not significant every year and also in the combined analysis (Table IV); and that every year yield differences were not significant, whether the fertilizers were applied directly to paddy or to the preceding crop of berseem in the rotation (Table V).

TABLE V. DIRECT AND RESIDUAL EFFECTS OF FERTILIZERS ON PADDY YIELDS (MD. PER ACRE)

Treatments	Years			
	1949–50	1950–51	1951–52	Average
C_0—Direct effects	16·14	29·15	24·95	23·58
C_1—Residual effects	14·24	29·22	23·16	22·58
'F' test	Not sig.	Not sig.	Not sig.	Not sig.
S.Em	±0·88	±0·76	±0·86	±0·54

TABLE VI. EFFECT OF SEASON ON PADDY YIELDS (MD. PER ACRE)

Years			
1949–50	1950–51	1951–52	Average
15·19	29·18	24·06	22·81
'F' test sig. at 1%	S.Em. ± 0·58	C.D. at 5% 1·63	C.D. at 1% 2·16

The season during 1950-51 was favourable to the one in 1951-52 which in turn produced significantly higher yields than 1949-50 (Table VI). The low yields in 1949-50 were due to subnormal rainfall in the months of August and September. Besides, high winds in the end of August and early September caused premature lodging of the crop resulting in partial sterility and subsequent loss in yield. In 1951, the failure of monsoons in the month of July and limited irrigation supplies from the canal adversely affected the initial growth of the crop. The situation improved later in August with normal rainfall and canal irrigation. In the month of September, with adequate irrigation, the deficit in rains was easily made up. The crop during 1950 produced the highest yields due to timely showers of rain and satisfactory irrigation supplies. It is, therefore, evident that seasonal effects played a more vital role in determining the yields of paddy than fertilization in paddy-berseem rotation.

Every year the nitrogen effects were not significant. The results (Table VII) conclusively prove that ammonium sulphate did not contribute in increasing fodder yields.

Both the doses of phosphate produced highly significant increases over control every year (Table VIII). On an average 80 lb. P_2O_5 dose recorded increase of

TABLE VII. EFFECT OF NITROGEN LEVELS ON BERSEEM FODDER YIELDS (MD. PER ACRE)

Treatments	Years			
	1949–50	1950–51	1951–52	Average
No nitrogen	681·0	676·2	452·2	603·1
30 lb. N/acre	683·2	680·8	471·4	611·8
60 lb. N/acre	673·7	665·2	472·9	603·9
'F' test	Not sig.	Not sig.	Not sig.	Not sig.
S.Em	±24·65	±23·41	±13·76	±15·40

TABLE VIII. EFFECT OF PHOSPHATE LEVELS ON BERSEEM FODDER YIELDS (MD. PER ACRE)

Treatments	Years			
	1949–50	1950–51	1951–52	Average
No phoshate	575·1	575·9	339·0	496·7
80 lb. P_2O_5/acre	738·9	707·3	509·4	651·9
160 lb. P_2O_5/acre	724·0	739·0	548·0	670·3
'F' test	Sig. at 1%	Sig. at 1%	Sig. at 1%	Sig. at 1%
S.Em	±24·65	±23·41	±13·76	±15·40
C.D. at 5%	69·97	66·53	39·08	43·70
C.D. at 1%	93·31	88·72	52·15	58·20

155·2 md. per acre. The higher dose of 160 lb. was at par with 80 lb. P_2O_5 in all the three years. The pooled analysis also showed that the average difference of only 18·4 md. per acre between the two doses was statistically not significant.

TABLE IX. DIRECT AND RESIDUAL EFFECTS OF FERTILIZERS ON BERSEEM YIELDS (MD. PER ACRE)

Treatments	Years			
	1949–50	1950–51	1951–52	Average
C_1—Direct effects	714·20	697·5	487·8	633·2
C_0—Residual effects	670·30	669·8	475·9	605·4
'F' test	Not sig.	Not sig.	Not sig.	Not sig.
S.Em	±20·12	±19·1	±11·2	±13·3

It is seen from Table IX that every year there were no significant differences in the yield of berseem whether the fertilizers were applied to berseem directly or to the preceding crop of paddy in the rotation.

TABLE X. EFFECT OF SEASON ON BERSEEM YIELDS (MD. PER ACRE)

Years			
1949–50	1950–51	1951–52	Average
679·5	673·7	465·5	606·2
'F' test Sig. at 1%	S.Em.± 7·8	C.D. at 5% 21·9	C.D. at 1% 29·0

The average yields in the years 1949-50 and 1950-51 were at par and significantly superior to the yield in the year 1951-52 (Table X). The prevalence of strong and hot winds during the greater part of April in the year 1952 produced an adverse effect on the growth of the crop and also resulted in the early drying of the green shoots. The yields of the last two cuttings in the months of April and May were, therefore, considerably reduced which accounted for lower yields in this year.

Interactions: None of the interactions were found to be significant every year and also in the pooled analysis for three years.

Thus in paddy-berseem rotation, only phosphate application to berseem produced significantly large yields of this crop. The average responses per lb. of P_2O_5 were found to be 159·7 and 89·30 lb. of green matter per acre for 80 lb. and 160 lb. P_2O_5 doses, respectively.

Economics of fertilization: Since only phosphate effects were found to be significant in increasing berseem yields, economics of manuring this crop with superphosphate were worked out at different price levels within feasible limits. The profits occurring at various fertilizer cost-berseem price points with 80 lb. P_2O_5 dose are given in Table XI. The relationship has been shown only for the lower dose since the difference in the responses due to 80 lb. and 160 lb. P_2O_5 levels was not found to be statistically significant.

TABLE XI. PROFITS FROM MANURING WITH 80 LB. P_2O_5/ACRE AT DIFFERENT PRICES OF PHOSPHATE AND GREEN BERSEEM

(RS. PER ACRE; 80 LB. P_2O_5 PER ACRE)

Price of berseem (Rs./md.)	Price of extra produce with response of 155·2 md./acre	Price per lb. of P_2O_5			
		0·50	0·60	0·70	0·80
0·60	93·12	53·12	45·12	37·12	29·12
0·70	108·64	68·64	60·64	52·64	44·64
0·80	124·16	84·16	76·16	68·16	60·16
0·90	139·68	99·68	91·68	83·68	75·68
1·00	155·20	115·20	107·20	99·20	91·20
1·10	170·72	130·72	122·72	114·72	106·72
1·20	186·24	146·24	138·24	130·24	122·24

It is evident from Table XI that application of superphosphate at 80 lb. P_2O_5 per acre produced a net profit of Rs. 29·12 even at such low price of Rs. 0·60 per md. of berseem and high cost of Rs. 0·80 per lb. of P_2O_5. At the prevailing cost between Rs. 0·60 and 0·70 per lb. of P_2O_5 and Rs. 1·00 per maund of berseem the net profit varies between Rs. 107·20 to 99·20 per acre.

DISCUSSION

In the present paper an attempt has been made to study the effects of superphosphate and ammonium sulphate on crop yields and economics of fertilization in paddy-berseem rotation. Both the fertilizers were either applied to paddy or berseem and their direct and residual effects were determined simultaneously. The results showed that ammonium sulphate at 30 lb. N level did not increase the yields of paddy crop in all the three years. At 60 lb. N level it was at par with 30 lb. N dose and significantly superior to no nitrogen treatment in only one out of three years. The consolidated result for three years also showed that there was no significant response to nitrogen applied either directly to paddy or to berseem in the rotation. In a number of experiments carried out at this Research Station since 1937, it has been found that ammonium sulphate is an excellent source of nitrogen in increasing paddy yields in fallow-paddy, Oat-paddy or wheat-paddy rotations but in berseem-paddy rotation it has proved ineffective due to high yields obtained in control plots (Khan and Bhatnagar, 1945; Ganguly and Relwani, 1954; Gupta and Relwani, 1957; Relwani, 1959). It seems that due to the beneficial functioning of the symbiotic nitrogen fixing bacteria associated with the nodules of berseem crop and the incorporation of rich residues into the soil, the nitrogen requirements of paddy crop are adequately met with. Although there is no direct evidence of this effect from the present type of layout due to absence of paddy after paddy plot, the high yields obtained from no nitrogen treatment provide a fairly strong support to such a conclusion.

Superphosphate at 80 lb. and 160 lb. P_2O_5 levels also proved to be ineffective in improving paddy yields. Such results have been previously reported by Gupta and Relwani (1957) and Relwani (1959) from this Station. This may be possibly due to the presence of adequate quantities of total and available phosphate in the soil to meet the demands of an early maturing variety of paddy. Besides, the availability of phosphate is known to increase under waterlogged conditions as reported by Mitsui (1955). Lack of response to phosphate has also been reported by Parthasarthy *et al.* (1936), Sethi *et al.* (1952), Chavan *et al.* (1957) and others.

As regards the application of fertilizers to berseem crop, superphosphate at 80 lb. P_2O_5 level produced significantly higher yield of 155·2 md. per acre than no-phosphate treatment. There was a further increase of 18·4 md. per acre with additional dose of 80 lb. P_2O_5 but this difference was statistically not significant over the initial level. It, therefore, appears that 80 lb. P_2O_5 dose is quite effective and the further increase in the level of fertilizer application is unnecessary. Sen and Bains (1952) have also reported 50 and 100 lb. P_2O_5 doses to be equally effective in maintaining the yields of berseem. Beneficial effects of phosphate in increasing green matter yields may be due to stimulus given to the symbiotic bacteria by this energy material. Higher berseem

yields by phosphate fertilization have also been shown by Parr and Bose (1944, 1945 and 1947), Sen and Bains (1951, 1955), Khan (1954) and Chandnani (1955).

There was no significant difference in the yields of berseem whether the phosphate was applied direct to berseem crop or to the preceding crop of paddy every year and in the pooled analysis for three years. Thus the residual value of phosphate was found to be as effective as the direct application. This may be due to temporary fixation of phosphate in the clay complex which prevents its being leached out from the soil. Besides, the fairly high phosphate status of the soil and large doses of phosphate applied seem to have contributed in levelling up yields from the two methods of application. This finding is, therefore, in conformity with the views expressed by Tisdale and Nelson (1955) that when higher rates of fertilizers are used and soil fertility increased, the problem of where the fertilizers should be applied becomes less important.

Ammonium sulphate on the other hand did not produce any beneficial effect on berseem yields. Parr and Bose (1945) also found that application of 80 lb. nitrogen per acre did not show any marked effect on the yield of berseem. Probably nitrogen fixing bacteria when provided with readily assimilable form of combined nitrogen become less active in fixing atmospheric nitrogen and thus retard nodule formation as mentioned by Hills (1918) and Gusev (1939). Recently some of the workers have reported positive response to dressings of nitrogenous fertilizers to legumes in small quantities due to vigorous start of the crop.

The economics of fertilization showed that 80 lb. P_2O_5 dose proved to be highly remunerative due to appreciable response of green berseem per pound of phosphoric acid.

SUMMARY

During the experiments on fertilizer requirements of paddy and berseem crops in the rotation for three years, sulphate of ammonia at 0, 30 and 60 lb. N and superphosphate at 0, 80 and 160 lb. P_2O_5 levels were applied in different combinations to either of the two crops every year, and direct and the residual effects studied. It was found that: (a) both ammonium sulphate and superphosphate applied directly to paddy or the preceding berseem crop did not produce significant increases in the yields of paddy; (b) berseem yields did not increase due to direct or residual effects of sulphate of ammonia; (c) superphosphate at 80 lb. P_2O_5 per acre showed a high response of 155·2 md. of green fodder per acre; (d) there was no significant difference in the yields of berseem due to 80 lb. and 160 lb. P_2O_5 doses; and (e) economically, 80 lb. P_2O_5 dose was found to be highly remunerative.

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MODERN TRENDS IN SEED TESTING

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THE Science of seed testing was born in the same decade in which Gregor Mendel published his famous experiments on peas. In 1869 the farmers of the district of Dresden (now in East Germany) approached Nobbe, the then Agricultural Adviser to the Government, and requested him to help them with the seed trade organisations. As such they were getting a very poor quality of seed that did not satisfy their requirements. Nobbe took the matter in his hands and investigated at first his own seed material which he was using for field experiments. He found in one case for example, that a sample sold under the name of *Festuca pratensis* had only 30 per cent of the genuine seed, whereas the rest was dirt, broken seeds, other crop seeds, and weed seeds. In order to protect the farmers from future losses, he went into the matter further and collected seed samples from the various seed trading agencies in the German Empire through the help of middle men. The seed traders knew nothing about his intentions and he got unsmuggled samples for investigation. Nobbe published his findings in 1876 in a book entitled "The Hand Book of Seed Science", which is the first of its kind in this field. He mentions there, for example, that in clover seeds (*Trifolium* spp.) quartz grains were always found in a definite proportion. As he investigated the matter, he was astonished to find, that both in Bohemia and in Hamburg there was one factory each, which manufactured the quartz grains on a large scale and called it 'clover quartz' as the grains were somewhat similar to the clover seeds in colour and in appearance. By mixing the quartz grains (about 5-10 per cent) with the clover seeds, some of the firms were making handsome profits. Obviously, this malpractice caused much annoyance and economic loss to the farmers.

The importance of the work of Nobbe (1869) began to be realised very soon. In the year 1870-71, 20 more departments for the investigation of seeds were set up at the agricultural research centres of the German Empire. Since then, the science of seed testing has been making steady progress.

Pal and Mukherji (1950) have reviewed the work of seed testing and certification in different countries of the world. They have emphasized the importance of seed testing and have made valuable suggestions for developing this field in India. The present article deals with some of the recent advances in the field of seed testing.

RECENT DEVELOPMENTS

(1) *Purity test and the identification of varieties:* The first task in the testing of a seed lot is to determine its purity. This requires exact analysis of the sample for the presence of inert matter, broken seeds, weed seeds and other crop seeds. In addition, it is sometimes desired to identify the variety correctly. This is not an easy task,

because due to the close relationship of the seeds, morphological characters for the identification of varieties are only of limited value. Special methods have, therefore, to be devised. Treatment of seeds or seedlings with different chemicals, the fluorescence of seeds, or other plant organs in ultra-violet light have usually been tried. The fluorescence method has often given very useful results.

The use of ultra-violet light from a quartz-lamp for the distinction between Italian and perennial rye grass (*Lolium* sp.), in which only Italian rye-grass gives fluorescence, is well known. For differentiating white oats from yellow oats in doubtful cases, and also for distinction between *Pisum sativum* and *P. arvense*, ultra-violet light has been used successfully. Recently attempts have been made to extend this method to other plants also.

Eifrig (1954) examined in ultra-violet light the liquid (water) in which seedlings of *Brassica* sp. had been growing in Lavollay's glass tubes. He observed, that the fluorescence of the liquid appeared early (in about three to five days of germination) in *Brassica rapa* var. *oleifera* and later in *B. oleracea* var. *sabauda* L. and *B. oleracea* var. *capitata* L.f. alba (6-8 and 12 days respectively). *Brassica napus* var. *oleifera* showed fluorescence only after 12-14 days of germination. The fluorescence was seen clearly only in normally germinating seeds. It is presumed by Eifrig (1954) that the synthesis of the fluorescent substance (or substances) could perhaps take place in the root of the seedling, if it did not already exist in the seeds. The process of synthesis or of further development (if the substance is already present in the seeds) is, however, dependent on suitable temperature. The longitudinal and cross sections of the roots showed that the fluorescent substance is localized in the cell walls of the central cylinder. Even sections of seeds showed blue to greenish-yellow fluorescence, thus making the existence of the fluorescent substance already in them possible. Several chemicals affected the fluorescence, e.g., H_2SO_4 (30 per cent) and HCl (15 per cent) caused quick disappearance, while acetic acid (10 per cent) and citric acid (10 per cent) produced marked reduction in fluorescence. In general, however, organic substances did not influence the fluorescence in any way. Whether the fluorescence differences would enable a distinction of the types and could give clues about the age of the seeds remains to be investigated.

Kamra (1958) observed slight differences in the root fluorescence of the different varieties of *Beta vulgaris* at seedling stages (14-day old). Sugar beets showed blue-white, sugar-fodder beets bluish-green, and fodder beets light-greenish fluorescence. With the use of an orange filter (Schott & Gen. G 111) the fluorescence colours could be seen slightly more clearly. The side roots in sugar beets gave a strong yellow fluorescence, which was of much less intensity in sugar-fodder beets. These differences in fluorescence colours could give useful clues for the identification of *Beta* varieties.

Some differences in ultra-violet fluorescence of seeds of *Phaseolus* varieties after treatment with phenol have also been observed by Weber-Dahlmann (unpublished).

Several chemicals have been tried from time to time to see, if the seeds show varietal differences in their response. Yamasaki (1957) treated seeds and seedlings of wheat, barley and rice with $KClO_3$ (0·8-4 per cent) for 18–72 hours at 17°C and 25°C. He observed that seeds or seedlings of wheat and barley, belonging to spring type, are more resistant to the action of $KClO_3$ than those belonging to the winter type.

He mentioned that in his earlier experiments (Yamasaki, 1955) the vernalized seeds of winter wheat showed increased resistance to the toxicant, as if they had changed into spring wheat. Further he observed that the seeds or seedlings of upland rice varieties which are resistant to drought showed increased toxicant resistance than the rice varieties less resistant to drought. On the basis of his observations, Yamasaki (1957) recommends the method of $KClO_3$ treatment for the identification of plant characters or types.

Kamra (1958) tried this method in *Beta vulgaris* and found that it did not work out the identification of seeds of sugar beets from those of sugar-fodder beets. Among the other methods tried by the same author were: the treatment of *Beta* seeds (clusters) with streptomycin sulphate, soaking of seeds in water for varying periods, action of absolute alcohol on clusters, photometric measurements of the liquid (water) in which the roots of the seedlings had been growing, the estimation of the sugar content of the seedlings with refractometer and paper-chromatography. Although interesting results were obtained with these methods, they could not be used for distinguishing sugar beets from sugar-fodder beets.

As mentioned earlier, due to the close resemblance of the seeds of different varieties, morphological characters have limited value for the identification of varieties. Eifrig (1953) reported that the different varieties of *Brassica napus*, *B. campestris*, and *B. oleracea* could be distinguished by the shape of the cotyledons, the primary leaves, the hairs on them, and the 1000 grain weight. In view of the fact that such samples for identification can be grown in artificial light, the long time needed for field trials can be profitably reduced. Eifrig (1953) could make the distinction of *Brassica* varieties in 10-21 days and of *Lactuca* varieties in 5-10 days, using 24 hours artificial light. This method is very useful for the seed testing work.

Plant breeders have introduced ‘ marker genes ’ in some varieties of crop plants for the quick identification of these varieties. Usually these genes express themselves in adult plants by influencing a definite character and thus the particular variety can be distinguished from the rest. However, in some cases, this effect is visible even in the seedlings. For instance, Kamra (1958) observed differences in the percentage proportions of pink and greenish-white hypocotyles of 14-day old seedlings of *Beta vulgaris*. The sugar-fodder beet variety ‘ Ovana ’ had 97·8 per cent pink seedlings, whereas the variety ‘ Rheinische Lanker ’ showed only 30·2 per cent. The sugar beet varieties tested (except for one) varied in their percentage of pink seedlings from 62·5 to 79·5. On the basis of these differences, useful clues could be obtained for the identification of seeds of sugar beets from those of sugar-fodder beets.

Kamra (1958) has also reported another interesting case where morphological characters could be used for the identification of a variety. Mangold (*Beta vulgaris* var. *cicla*) is used solely for human consumption and has seeds which are very similar to those of sugar, sugar-fodder and fodder beets. As mixtures often occur, a method of distinction was highly desirable. Kamra (1958) observed that the variety ‘ Lukullus ’ could be distinguished from the rest of the Mangold types as well as the other *Beta vulgaris* varieties on the basis of its yellow-green cotyledons as against the dark-green ones of all the others. This is one of the rare examples, where colour differences in the cotyledons are useful for identification of a variety.

(2) *Germination:* The next important step in testing a seed lot is to determine its germination percentage. This can be done by germinating the seeds on filter paper or in sand or soil and counting the number of normal sprouts (as well as abnormal sprouts separately) after a definite number of days. Simple as this method appears, nevertheless, it has its own complications.

For germination, seeds usually show special requirements, e.g., temperature, humidity, light and darkness, which are not only different for different types of seeds, but sometimes could vary even with different samples of the same type. Special apparatus and arrangements are, therefore, required for studying germination.

Of greater importance, however, are two more difficulties, which need special mention: (i) the germination tests generally take a long time for completion, sometimes too long for practical purposes; and (ii) where germination-inhibiting substances occur in the seeds (e.g., in freshly harvested barley) or seeds are dormant due to some other reasons, the germination trials fail completely. In view of these difficulties, it is necessary to develop quick methods for determining the viability of seeds. The methods so far tried by various workers include the growing of excised embryos in artificial media, or to use the activity of specific enzyme systems in the seeds, or certain dyes as indicators of viability.

The growing of excised embryos *in vitro*, although a reliable method, presents its own problems. The difficulty experienced in excising embryos without injury, the small size of many of the seeds received for testing, and difficulties encountered in keeping the growth media sterile, prevent the free usage of this method in the testing of most agricultural and vegetable seeds. In the International Rules for seed testing, there is no provision for this method.

The activity of such enzymes, as catalase and oxidase as a measure of seed viability has been tried by numerous workers. The conflicting data and the requirement of special equipment, have made its application impracticable to routine seed testing work.

The methods involving the use of dyes are of two kinds. One depends upon the impermeability of living cells to certain stains which readily enter and stain dead tissues. The second method involves the reduction of certain colourless compounds which are strongly coloured in their reduced states. With this method the living cells become strongly coloured and the non-living tissues remain unstained. In practice, the second method has proved superior to the first. Earlier experiments of this method were made with selenium salts, but this chemical did not become universally popular, because of its toxicity to human beings. Lakon (1942) replaced selenium with tetrazolium and obtained satisfactory results. In addition, he found that 2, 3, 5 triphenyl-tetrazolium chloride was superior to 2, 3-diphenyl-5-methyl-tetrazolium chloride. Solutions of different concentrations were tried, but in general, it appeared that 1 per cent solution gave most satisfactory results with several species of seeds. Initially used for cereals, this chemical has since been extended to a large number of agricultural and vegetable crops chiefly through the efforts of Lakon and his associates in Germany.

However, some investigators from the U.S.A., England and some other countries have expressed the view, that this method can be used only as a rough measure of seed

viability. They observed that although high-germinating seed will stain easily and dead seed not at all, the correlation between staining and germination of seed of intermediate viability and of low vigour is very poor. Apparently a staining test does not directly measure the plant-producing power of seeds which may be diseased, mechanically injured or insect damaged. Perhaps because of these reasons, the use of the tetrazolium method is limited. The International Rules for Seed Testing recommend it only for seeds of trees, such as *Carpinus*, *Fraxinus*, *Pinus*, *Texas*, *Prunus* and *Pyrus*, which germinate too slowly to be tested by regular germination procedures.

It is, therefore, clear that although tetrazolium chloride has proved to be the most satisfactory of all the dyes tried so far, further research is necessary to clarify some of the problems associated with the determination of seed viability.

Recently some Swedish workers (Simak and Gustafsson, 1953; Simak, *et al.*, 1957) have developed a new method for determining the viability of seeds with the help of soft X-rays (Grenz rays). Fig. 1 shows the apparatus used by these workers. This technique has the important advantage over the use of dyes,

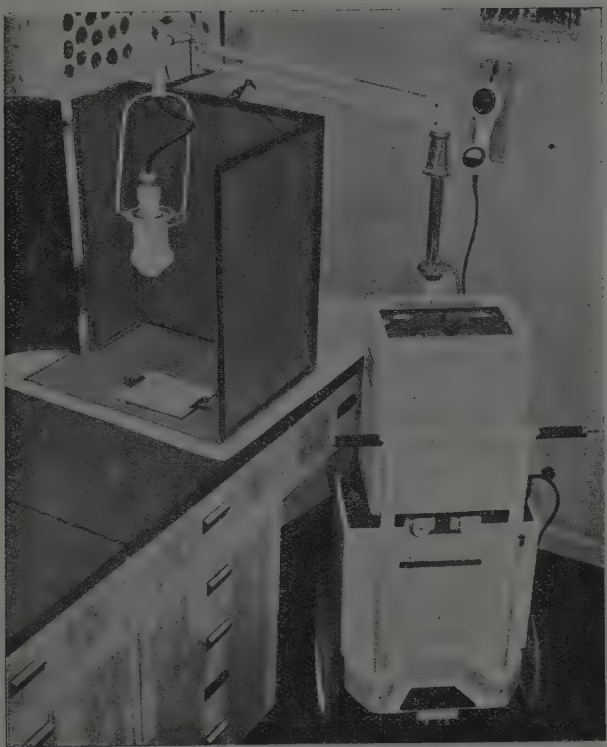

Fig. 1. Apparatus used for X-ray photography of seeds

that the seeds do not get damaged through exposure to these rays. The doses given are generally very small (usually about 10-15 r or less) which are far below the critical values for the seeds, and hence they can be germinated afterwards to test their viability directly. From a good X-ray photograph of seeds, it is possible to obtain the following information: (i) Quantitative differences in the development of the embryo and the endosperm; full seeds can be easily distinguished from the empty ones. (ii) The qualitative properties of the embryo and the endosperm. As the physiological destruction of the embryo cannot be detected by ordinary methods of X-ray photography, the seed material is impregnated with salts of heavy metals, e.g., barium chloride. Dead parts of the seed absorb the chemical whereas the living cells do not, on account of their differentially permeable membranes. These differences are clearly visible on the X-ray photograph (Fig. 2). Experiments with pine seeds show

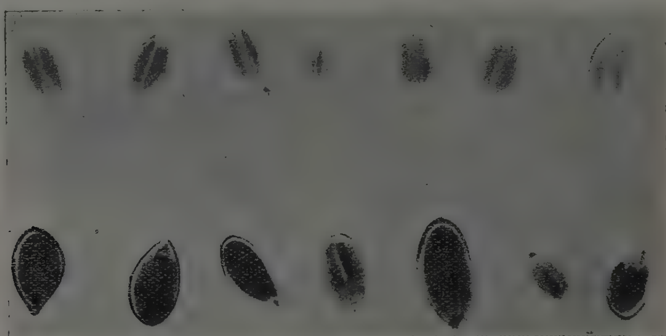

FIG. 2. TWO SAMPLES OF *Pinus silvestris* SEEDS TREATED WITH 15% BARIUM CHLORIDE SOLUTION FOR 24 HOURS

Above: FRESHLY HARVESTED SEEDS. HIGH VITALITY, PRACTICALLY 100% GERMINATION. NO ABSORPTION OF BARIUM CHLORIDE.

Below: SEEDS SEVERAL YEARS OLD AND DEAD. BARIUM CHLORIDE HAS BEEN ABSORBED.

a distinct connection between seed viability and degree of impregnation of barium chloride (Gustafsson *et al.*, 1957). (iii) It is possible to estimate the extent of insect damage to the seeds by this method, as one can directly see either the larvae or their excrements in the seeds. (iv) The mechanical damage to the seeds resulting from rough threshing, seed extraction and other operations can also be noticed on the X-ray photographs. The authors describe in detail, how this method can be usefully employed for routine seed testing work. It is also mentioned that although this method has been worked out with tree seeds, it is being extended to the agricultural and vegetable crops seeds and the results obtained so far are promising.

At the Indian Agricultural Research Institute, New Delhi, Swaminathan and Kamra (1961) have studied the anatomical and viability characteristics of seeds of 16 species of agricultural, horticultural and vegetable plants using the X-ray contrast method of Simak and Gustafsson (1954). The data revealed that the method can be used to assess correctly the germination potentialities of seed samples.

Both mechanical injuries to the embryo and insect infestation could be readily detected. The presence of more than one embryo could also be easily seen in polyembryonic seeds. By soaking seeds in $BaCl_2$ solution prior to photography, the physiological soundness of aged seeds as well as of seeds stored without special precautions could be accurately determined. Seeds with massive endosperms such as those of cereals showed some impregnation of $BaCl_2$ in the endosperm but they proved to be viable so long as the embryo remained free of impregnation and the endosperm did not get heavily impregnated.

(3) *Dormancy:* An account of the germination will not be complete without making a mention of dormancy. Barton (1952) points out that this term has not been defined properly in literature. She applies the term ' primary dormancy ' to the failure of viable seeds to germinate when they are placed under conditions of moisture and temperature which would ordinarily bring about sprouting. However, it is important to know that failure of seeds to germinate is not in all cases due to dormancy. The loss of viability might have resulted from aging or from unfavourable storage conditions. Even the seeds could be without embryos. The term ' secondary dormancy ' is usually applied to the failure of such seeds to germinate which were initially non-dormant but due to unfavourable storage conditions have passed into a state of dormancy.

That the storage conditions largely affect the germination capacity of seeds is a matter of common observation. In general, a low relative humidity together with a high temperature have been reported to favour the formation of ' hard seeds ', whereas, a high relative humidity and a low temperature produced the reverse effect. ' Hard seeds ' are usually found in legumes and are those which due to impermeable testa do not absorb water and remain hard till the end of the germination test. The reports on the effects of temperature on the storage of seeds are contradictory.

Stuetz (1933) observed that seeds of lucerne, red clover, white clover and alsike clover stored at low temperature and high relative humidity showed less hard-seededness than those stored at about 18°C and low relative humidity.

Hopkins *et al.* (1947) found that the percentage of hard seeds in bean (*Phaseolus vulgaris*) increased directly with the storage temperature and inversely with the relative humidity. However, from their results these workers were not certain whether the temperature played any role in the formation of hard seed-coat apart from its effect on the moisture content of the seeds.

Nutile and Nutile (1947) stored nine varieties of bean (*Phaseolus vulgaris*) at different relative humidities for 60 days. They observed that although there were varietal differences, in general, the lower the moisture content of the seeds, the greater was the percentage of hard seeds formed. All varieties showed a percentage of hard seeds at low relative humidities.

Harrington (1949) found that by storing seeds of ' Kentucky Wonder ', a variety of bean (*Phaseolus vulgaris*), at different relative humidities, the seed moisture content and the percentage of hard seeds varied according to the relative humidity at which samples were stored. Storage at 10 per cent relative humidity produced the maximum percentage of hard seeds.

Hurwitz and Gabrielith-Gelmond (1952) concluded from their experiments

on the storage of sweet lupins (*Lupinus luteus*) under different conditions that the factor chiefly responsible for the hardening of the seeds is the low relative humidity of the air and not high temperature. Joubert (1954) also expressed the same opinion as a result of his experiments with the variety 'Green Savage' of bean.

It would, therefore, appear that the relative humidity of the air perhaps plays a more important role than temperature as far as the formation of hard seeds in legumes during storage is concerned.

SEED TESTING IN INDIA

As mentioned earlier, Pal and Mukherji (1950) have emphasized the importance of seed testing work in India and have made very useful recommendations for starting this work in this country. Under the Second Five Year Plan, the Government of India sanctioned a project for the setting up of a Central Seed Testing Laboratory at the Indian Agricultural Research Institute, New Delhi, and it started functioning in November, 1955. Steps have also been taken to set up a chain of regional seed testing and certification laboratories in several States of India. Some such laboratories have already come into existence, as for example, at Ludhiana, Patna and Srinagar and others are expected to be established in the near future. These regional laboratories will be mainly responsible for seed testing, certification and field inspection of vegetable crops, in the first instance, in their respective States.

The Central Seed Testing Laboratory at the Indian Agricultural Research Institute, New Delhi, is entrusted with the work of conducting research on vegetable seeds towards fixing minimum standards of purity, germination, and freedom from pests and diseases, suited to Indian conditions. Satisfactory progress has been made by this laboratory towards the achievement of its objectives. More than 2,000 samples collected from different parts of India have been tested. There has also been good progress towards the developing of new techniques suited to Indian conditions for the quick determination of viability of seed samples. A museum of weed seeds and of the varieties of vegetable crops is also being established.

Under the Third Five Year Plan, it is intended to expand this laboratory so as to include work on all important agricultural crops. The laboratory also undertakes fundamental research on the various aspects of seed testing. In addition, the Central Seed Testing Laboratory would also function as a training centre. The Institute has already a comprehensive programme of post-graduate training leading to the M.Sc. and Ph.D. degrees in several disciplines related to the agricultural science. Training in modern methods of seed testing and certification would form an integral part of this programme.

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STUDIES ON WEED CONTROL IN WHEAT

I. EFFECT OF PRE- AND POST-EMERGENCE APPLICATION OF 2,4-D, HAND-WEEDING AND INTERCULTURE ON THE WEEDS AND YIELD OF WHEAT

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Russell and Watson (1940) stated that wheat is ill fitted to stand competition from weeds. This is also borne out from the results of several other workers who have studied the effect of weed competition in this crop. Mc Rostie (1932), Pavlychenko and Harrington (1935), and Godel (1938), reported a reduction in yield of 80·4, 40·0 and 34·8 per cent, respectively, under varying degrees of weed competition. The effective control of weeds in this crop is, obviously essential for good yield.

The practice of hand-weeding and hoeing commonly followed in India suffer from certain inherent drawbacks. Hand-weeding is slow, laborious and expensive, and as such it cannot be practised on extensive scale. Hoeing on the other hand is ineffective against weeds in the crop row which are the keenest competitors of the crop. Hoeing may also harm surface feeding roots (Russell, 1952). Furthermore, unless these cultural operations are repeated often, weeds germinating from fresh weed seeds soon re-infest the fields. It is, therefore, hardly surprising that with the introduction of selective weedicides like 2,4-D and MCPA, cultural methods of weed control in cereals have been almost completely replaced in agriculturally advanced countries.

In India too, very keen interest has been shown in this subject in recent years. Asana (1951, 1952), Shivpuri and Sinha (1953), Pande (1953, 1954), and Verma and Bhardwaj (1957, 1959) have shown that most of the common weeds in wheat can be effectively controlled by 2,4-D with substantial increases in yield. There is, however, lack of data on the comparative merits particularly from the point of view of economics of weed control by 2,4-D and the traditional methods of hoeing and handweeding. Obviously, unless control of weeds by 2,4-D proves more effective and economical and is substantiated by reliable data, our farmers can hardly be expected to change to this new method of weed control.

The present experiment was, therefore, designed to evaluate from all aspects the effect of application of 2,4-D at different rates and times of application to wheat crop in comparison to hand weeding and hoeing by bullocks. The results are briefly presented in this paper.

MATERIAL AND METHODS

The experiment was carried out in the Division of Agronomy, Indian Agricultural Research Institute, New Delhi for three years (1955-56 to 57-58) with the following

ten treatments, replicated four times in a randomized block design. Treatments were applied to the same plots for three years and hence the data for 1956-57 and 1957-58 represent the two and three years' cumulative effects of treatments respectively.

Treatments

A Unweeded control
B Hand-weeding (One hand-weeding with *khurpi*)
C Interculture (One hoeing with bullocks with *desi* plough)
D Post-emergence 2,4-D ½ lb. (Acid equivalent)
E Post-emergence 2,4-D 1 lb.
F Post-emergence 2,4-D 2 lb.
G Interculture + Post 2,4-D ½ lb.
H Pre-emergence 2,4-D ½ lb.
I Pre-emergence 2,4-D 1 lb.
J Pre-emergence 2,4-D ½ lb. + Post 2,4-D ½ lb.

The gross size of the plot was 18 ft.×21 ft. and the net plot from which all observations and yield was recorded was 16 ft.× 18 ft.

Wheat variety N.P. 718 was sown in the second week of November every year, except in 1955-56 when sowing had to be delayed to November 30 due to late rains.

Pre-emergence application of 2, 4-D was made one day after sowing. Post-emergence spray with 2, 4-D, hand-weeding and bullock hoeing was done six weeks after sowing. Ammonium sulphate at 30 lb. nitrogen per acre was applied at first irrigation to all the plots. Weedicide (sodium salt 80 per cent a. e.) was applied with a foot sprayer in about 50 gallons of water.

Weed population studies at each observation were made by placing a quadrate 2 ft.× 2 ft. randomly at five places in each plot. The number of different species within the quadrant was recorded.

RESULTS

A. *General*

1. *Degree of weed infestation:* An idea of the degree of weed crop competition can be had from Table I which gives the mean population of weeds and the crop in the control plot, for the three years.

TABLE I. CROP-WEED COMPETITION IN DIFFERENT YEARS IN THE CONTROL PLOT (PER 20 SQ. FT.)

Crop/weed population	1955–56	1956–57	1957–58	Mean
Mean plant population	225·5	160·0	165·0	183·5
Mean weed population	224·5	938·0	1,050·0	737·5

The data in Table I clearly show that the weed competition was low in 1955-56 (partly due to late sowing) but the weed intensity was very high during the second and third year of the experiment. In the first year, for each wheat plant there was only one weed plant but during second and third year this ratio was of the order of 5·9 and 6·4 respectively.

2. *Dominant weed species:* The different weed species present in the experimental field (control plots) and their relative intensity are given in Table II.

TABLE II. RELATIVE INTENSITY OF DIFFERENT WEED SPECIES IN THE EXPERIMENT

Weeds	Common Indian name	Percentage of total weed population		
		1955–56	1956–57	1957–58
NON-GRASSES				
Anagallis arvensis L.	Krishn Nil	59·9	68·3	56·6
Medicago denticulata	Maina	13·8	13·9	12·9
Melilotus parviflora	Senji	6·2	7·6	18·1
Heliotropium ovalifolium Forsk	Untchara	5·6	0·05	0·03
Launea aspleniifolia Cass.	Jungli Gobhi	3·0	1·0	1·10
Chenopodium album L.	Bathu	1·8	0·6	3·2
Cyperus rotundus L.	Motha	1·3	4·8	3·7
Fumaria parviflora Lamk.	Pitpara	0·2	0·3	0·5
Euphorbia dracunculoides Lamk.	Chhotidudhi	0·4	0·16	0·03
Vicia hirsuta koch.	Chatrimatri	0·1	0·4	0·2
Convolvulus arvensis L.	Hiran Khuri	0·2	0·4	0·16
Asphodelus tenuifolius Cavan.	Piazi	0·3	1·1	1·5
Brassica sp.	Wild mustard	0·1	0·03	0·02
Lathyrus aphaca L.	Matri	..	..	0·15
Carthamus oxyacantha Bieb.	Pholi	..	..	0·15
GRASSES				
Cynodon dactylon Pers.	Dub	6·8	1·2	2·2

The data show that the most dominant weed in the experimental field was *Anagallis arvensis* which constituted about 60 per cent of the total weed population during all the three years. Other important weeds were *Medicago denticulata, Melilotus parviflora* and *Cynodon dactylon* (only in 1955-56).

B. *Effect of Treatments on Weeds*

1. *Effect of treatments on weed population:* The data on the weed population taken

40, 80 and 120 days after sowing (I, II and III observation) are presented in Table III. Data on weed population recorded on 40th day indicate the effect of pre-emergence application of 2,4-D only in the first year, as other treatments were applied after this count. In the second and third year, however, the first weed count gives the cumulative effect of previous year plus effect of pre-emergence application in the particular year. Data on 80th and 120th day in the second and third year relate to two years' and three years' cumulative effect of treatments.

(a) Pre-emergence application of 2,4-D: First weed count in the first year shows only the effect of pre-emergence treatment (H, I, J). It will be noted that pre-emergence application of 2,4-D did not cause any marked reduction in weed population under purely pre-emergence treatments (H, I) was noted at the I, II and III observation. Furthermore, no residual effect of pre-emergence treatment was observed on weed population, and in 1956-57, the weed population at 40th day in the pre-emergence treated plots (H, I) was significantly higher than in plots treated with 2,4-D at post-emergence stage in the previous year (D, E, F).

(b) Post-emergence application of 2,4-D: The data of II weed count in Table III show the high efficiency of post-emergence 2,4-D in reducing the stand of weeds. Reduction in total weed population due to $\frac{1}{2}$, 1 and 2 lb. doses of 2,4-D were 84·5, 91·2 and 95·8 per cent, respectively, over control. Though, 2,4-D at 2 lb. gave the best weed control, differences among the three levels were not significant. It will also be observed that the weeds that survived under 2,4-D treatments were mostly grasses (*Cynodon dactylon*). Furthermore, little regeneration of weeds was observed after the treatment.

Data of the I observation in 1956-57 and 1957-58 show that the post-emergence treatments had high residual (1956-57) and cumulative (1957-58) effects on weed population. Due to the residual effect of post-emergence 2,4-D weed population in treatments E and F was significantly less than control.

(c) 2,4-D Pre+Post: A combination of Pre + Post-emergence application of 2,4-D (treatment J) was more effective in the control of weeds than the pre- or post-emergence 2,4-D alone.

(d) Hand-weeding: All weeds were cleared with *khurpi* in hand-weeded plots on 40th day after sowing (just after taking the first weed count). Unlike the post-emergence 2,4-D treatment where little regeneration of the susceptible species of weeds was noted, several weeds had again infested the hand-weeded plots by 80th day.

Like the post-emergence 2,4-D, hand-weeding also had significant residual and cumulative effect on weed population though of a lower degree than the former treatment.

(e) Interculture: Hoeing also gave satisfactory control of weeds. In regard to regeneration and residual effect of treatments on weeds, hoeing was less effective than hand-weeding.

(f) Hoeing + 2,4-D: Combining the 2,4-D treatment just after hoeing proved more effective as far as control of weeds was concerned than either treatment applied singly.

2. *Effect of treatments on dry weight of weeds:* After recording the weed count at I

TABLE III. RELATIVE EFFECT OF TREATMENTS ON WEED POPULATION (INTENSITY OF WEED PER 20 SQ. FT.)

Year	Observation	Days after sowing	Control	Cultural		Post 2,4-D			Cultural + Post 2,4-D	Pre 2,4D		Pre+Post 2, 4-D	S.Em. ±	C.D. at 5%
			A	B	C	D	E	F	G	H	I	J		
1955–56	I	40	209	192	169	184	207	181	200	157	177	193	17·89	N.S.
	II	80	225	61	68	52	30	13	31	141	132	53	6·93	19·13
	III	120	125	75	75	47	26	6	24	93	89	50	84·28	28·55
Percentage reduction over control*		..	..	72·9	69·8	76·9	86·7	94·2	86·2	37·3	41·3	76·5	..	..
1956–57	I	40	859	617	609	557	477	267	555	988	737	583	116·8	339·1
	II	80	938	264	409	168	88	25	124	1955	567	105	117·4	340·7
	III	120	741	326	338	133	90	24	108	333	271	124	46·4	134·6
Percentage reduction over control*		..	..	71·9	56·4	82·1	90·6	97·3	86·8	−11·2	39·6	88·8	..	..
1957–58	I	40	903	402	492	395	307	269	314	178	126	112	55·15	160·1
	II	80	1050	277	406	59	40	44	34	242	100	34	23·62	68·5
	III	120	625	229	290	35	16	16	26	127	45	28	15·59	45·2
Percentage reduction over control*				73·6	61·3	94·4	96·2	95·8	96·8	77·0	90·5	96·8	..	..
Mean % reduction				72·8	62·5	84·5	91·2	95·8	89·9	34·4	57·1	87·4	..	..

*Percentage reduction in weed population was worked out from the data of II observation.

and III observations these weed plants from 20 sq. ft. area in each plot were uprooted and the fresh and dry weight of the shoots recorded. The data are given in Table IV.

The data show that the treatments had highly significant effect on the dry weight of weeds. During 1955-56, though the pre-emergence treatments (H, I, J) had not caused significant reduction in weed population at 40 days yet the weight of weeds was significantly reduced under these treatments. Even at 120 days there was significant reduction in the weight of weeds under pre-emergence 2,4-D.

TABLE IV. DRY MATTER OF WEEDS AS INFLUENCED BY DIFFERENT TREATMENTS (GM. PER 20 SQ. FT.)

Treatment	At 40 days			Mean	At 120 days			Mean
	1955–56	1956–57	1957–58		1955–56	1956–57	1957–58	
Control								
A	15·2	36·7	35·0	29·0	61·8	167·5	185·2	138·2
Cultural								
B	15·0	25·5	24·8	21·8	19·0	39·0	39·2	32·4
C	14·0	28·7	29·2	24·0	32·2	77·7	87·5	65·8
Post 2,4-*D*								
D	13·8	23·5	21·5	19·6	21·0	25·5	22·0	22·8
E	15·2	18·7	17·2	17·0	18·0	14·5	12·5	15·0
F	14·5	15·0	14·8	14·8	15·2	6·7	7·0	9·6
Cultural + *Post* 2,4-*D*								
G	14·8	24·2	19·8	19·6	15·0	14·2	16·0	15·1
Pre 2,4-*D*								
H	12·8	30·0	10·5	17·8	28·5	71·5	34·8	44·9
I	11·2	24·7	7·8	14·6	26·5	63·7	23·7	38·0
Pre + *Post* 2,4-*D*								
J	13·0	22·2	6·5	13·9	16·2	17·3	10·2	14·6
S.Em.	±0·56	±2·22	±1·99	±1·07	±1·91	±9·76	±4·19	±3·97
C.D. at 5%	1·62	6·40	5·77	3·105	5·53	28·31	12·18	11·52

Other treatments, viz., 2,4-D post, hoeing and hand-weeding showed more or less similar effect on dry weight of weeds as on weed population. Post-emergence application of 2,4-D caused the highest reduction of the order of 84·5, 90·2 and 93·1 per cent at ½, 1 and 2 lb., respectively.

3. *Relative susceptibility of different weed species to post-emergence application of 2,4-D:* Since post-emergence 2,4-D (Table V) proved most effective against weeds it was considered important to evaluate the relative effectiveness of this weedicide against different weed species. The data were, therefore, worked out on the basis of reduction caused in the population of different weed species at the II observation (80 days) in relation to I observation (40 days) under the three levels of 2,4-D. (D, E, F).

TABLE V. SUSCEPTIBILITY OF WEED SPECIES TO POST-EMERGENCE 2,4-D. PERCENTAGE KILL (AVERAGE OF THREE YEARS)

Weed species	Rate of 2, 4-D		
	½ lb.	1 lb.	2 lb.
Chenopodium album	91	97	100
Convolvulus arvensis	89	100	100
Asphodelus tenuifolius	50	89	100
Heliotropium eichwaldii	99	100	100
Anagallis arvensis	88	95	99
Vicia hirsuta	88	100	100
Melilotus parviflora	58	51	100
Medicago denticulata	52	72	94
Launea asplenifolia	80	89	100
Wild mustard	100	100	100
Fumaria parviflora	72	85	100
Euphorbia dracunculoides	90	100	100
Lathyrus aphaca	100	100	100
Carthamus oxyacantha	100	100	100
Cyperus rotundus	29	48	47
Cynodon dactylon	–60	–21	– 7

The data show that most of weed species infesting the wheat crop were susceptible to 2,4-D. Even at ½ lb. rate this weedicide caused more than 80 per cent kill of *Chenopodium album*, *Convolvulus arvensis*, *Heliotropium eichwaldii*, *Anagallis arvensis*, *Vicia hirsuta*, *Launea asplenifolia*, *Euphorbia dracunculoides*, *Lathyrus aphaca* and *Carthamus oxyacantha*. At this rate *Asphodelus tenuifolius*, *Melilotus parviflora*, *Medicago denticulata*, *Fumaria parviflora* and *Cyperus rotundus* were less susceptible and *Cynodon dactylon* was resistant to the weedicide. Though 2 lb. rate gave most effective control of all weeds such high rate of 2,4-D application was, however, not desirable from the yield point of view (Table IX).

C. *Effect of Treatments on Crop*

Germination: Post-emergence treatments were applied six weeks after sowing and as such they were not expected to have any effect on the germination of the crop. Effect of pre-emergence treatments on the germination is given in Table VI.

TABLE VI. EFFECT OF PRE-EMERGENCE 2,4-D ON THE GERMINATION OF WHEAT

	Number of wheat plants per 10 linear ft.			
	1955–56	1956–57	1957–58	Mean
Control	108·7	79·5	80·1	89·4
½ lb. 2,4-D	108·3	74·8	81·1	88·1
1 lb. 2,4-D	102·8	82·0	84·0	89·6
S.Em. for control	±2·43	±1·61	±1·74	±1·112
For ½ lb. 2,4-D	±4·56	±3·01	±3·25	±2·08
For 1 lb. 2,4-D	±6·44	±4·25	±4·60	±2·94
C.D. at 5%	N.S.	N.S.	N.S.	N.S.

Data in Table VI show that pre-emergence application of 2,4-D had no adverse effect on germination of the crop.

Growth: Two growth characters, namely, number of tillers and height of the main shoot were studied. Effect of treatments on these characters is given in Table VII. It is seen that the treatments had no significant effect on height of shoot. They also did not show marked effect on tillering during 1955-56, but during 1956-57 and 1958-59, the effect was quite apparent. Though in 1956-57 treatment differences were not significant, hand-weeding and 2,4-D post-emergence at 1 lb. caused about 25 per cent increase in the number of tillers over control. During 1957-58, all the treatments produced significantly higher number of tillers than control.

Effect on yield attributes: Data on the effect of treatments on yield attributes recorded at harvest are given in Table VIII. It is seen that final stand, number of grains per earhead and 1,000 grain weight were not affected significantly by treatments. Treatments, however, had significant effect on the number of effective tillers. Treatments B and E gave significant increase in the number of effective tillers during all the three years. In 1957-58 all the treatments produced more effective tillers than control. Mean analysis for three years showed that all the treatments were significantly superior to control in the production of effective tillers. Further it will be noted that the effects of treatments (in particular chemical) were more pronounced during the second and third year than during first year (1955-56).

Effect on yield: Effect of treatments on the yield of wheat grain and straw are given in Table IX. Data show that wheat crop responded favourably to weeding. All the treatments caused marked increase in yield over control though the differences slightly

TABLE VII. EFFECT OF TREATMENTS ON TILLERS AND HEIGHT OF MAIN SHOOT

Plant character	Year	Treatments: Control	Cultural		Post 2,4-D			Cultural + Post 2,4-D	Pre 2,4-D		Pre + Post 2,4-D	S.Em ±	C.D. at 5%
		A	B	C	D	E	F	G	H	I	J		
No. of tillers per plant	1955–56	2·50	2·70	2·40	2·45	2·57	2·30	2·20	2·10	2·12	2·35	0·24	N.S.
	1956–57	2·00	2·52	2·35	2·37	2·50	2·37	2·32	2·32	2·37	2·42	0·097	N.S.
	1957–58	2·00	2·62	2·20	2·42	2·62	2·45	2·37	2·25	2·40	2·47	0·064	0·187
	Mean	2·17	2·61	2·32	2·41	2·56	2·37	2·30	2·22	2·30	2·41	0·092	0·266
Height of main shoot (cm.)	1955–56	103	102	107	105	103	104	102	98	104	103	2·09	N.S.
	1956–57	101	106	100	105	105	98	101	102	103	103	1·61	N.S.
	1957–58	100	109	102	106	106	105	106	104	106	107	1·88	N.S.
	Mean	101	106	103	105	105	102	103	101	104	104	1·206	N.S.

TABLE VIII. EFFECT OF TREATMENTS ON YIELD ATTRIBUTES

Plant character	Year	Treatments: Control	Cultural		Post 2,4-D			Cultural +Post 2,4-D	Pre 2,4-D		Pre+ Post 2,4-D	S.Em. ±	C.D. at 5%
		A	B	C	D	E	F	G	H	I	J		
Final stand of the crop (Plants per 10 linear ft.)	1955–56	105	99	103	102	98	99	102	104	96	98	5·76	N.S.
	1956–57	75	78	76	78	75	77	68	72	77	72	3·52	N.S.
	1957–58	77	71	79	73	79	72	74	76	81	77	3·56	N.S.
	Mean	86	83	86	84	84	83	81	84	85	82	2·48	N.S.
Number of effective tillers per plant	1955–56	1·80	2·12	1·86	1·92	2·00	1·92	1·67	1·77	1·82	1·92	0·687	0·199
	1956–57	1·80	2·27	2·05	2·18	2·25	2·07	2·02	2·10	2·15	2·10	0·066	0·191
	1957–58	1·77	2·42	2·00	2·37	2·45	2·22	2·10	2·15	2·17	2·25	0·11	0·318
	Mean	1·79	2·27	1·97	2·16	2·23	2·07	1·93	2·01	2·05	2·09	0·047	0·136
No. of grains per earhead*	1955–56	30·6	33·9	32·7	31·8	32·7	30·6	30·9	31·5	31·5	31·2	1·59	N.S.
	1957–58	30·3	35·1	32·7	34·8	34·8	32·7	33·6	33·0	34·2	33·3	0·973	N.S.
	Mean	30·5	34·5	32·7	33·3	33·7	31·6	32·2	32·2	32·8	32·2	0·88	N.S.
1,000 grain weight*	1955–56	35·1	35·2	35·2	35·3	35·2	35·1	35·3	35·4	35·2	35·2	0·091	N.S.
	1957–58	35·1	35·3	35·3	35·3	35·5	35·2	35·3	35·1	35·2	35·3	0·116	N.S.
	Mean	35·1	35·2	35·2	35·3	35·3	35·1	35·3	35·2	35·2	35·2	0·067	N.S.

*Studies could not be made during 1956–57 as the crop was damaged by hailstorm.

fell short of significance during 1955-56 and 1956-57. Differences during 1957-58 were, however, highly significant. Mean analysis for three years also indicated highly significant response of wheat crop to weed control treatments. Hand-weeding (B) and 2,4-D post-emergence at 1 lb. (E) gave the best results, and average increase in yield over control due to these treatments was of the order of 26·7 and 19·0 per cent, respectively, the differences being highly significant. Treatments D and F (2,4-D post at ½ and 2 lb.) also caused significant increase in yield over control. No significant differences existed between hand-weeding (B), 2,4-D post-emergence at 1 lb. (E) and 2,4-D post-emergence ½ lb. (D).

TABLE IX. YIELD OF GRAIN AND STRAW AS AFFECTED BY TREATMENTS

Plant character	Year	Treatments										S.Em. ±	C.D. at 5%
		Control	Cultural		Post 2,4-D			Cultural+ Post 2,4-D	Pre 2,4-D		Pre+ Post 2,4-D		
		A	B	C	D	E	F	G	H	I	J		
Yield of grain md./acre	1955–56	16·1	19·5	17·3	16·4	17·4	17·1	13·4	13·3	17·2	16·4	1·275	N.S.
	1956–57	10·7	12·9	11·3	12·2	12·8	11·4	11·6	10·7	11·0	11·4	0·78	N.S.
	1957–58	15·9	21·6	16·8	20·5	20·6	19·1	18·4	19·0	19·3	20·8	0·89	2·58
	Mean	14·2	18·0	15·1	16·4	16·9	15·9	14·5	14·3	15·8	16·2	0·671	1·947
Percentage increase over control		..	26·7	6·3	15·5	19·0	12·0	2·1	0·7	11·3	14·1		
Yield of straw md./acre	1955–56	35·6	41·2	32·6	35·2	35·6	36·0	26·6	24·9	35·0	33·9	2·13	N.S.
	1956–57	55·7	61·5	57·2	58·6	60·1	59·6	49·9	55·3	57·7	59·6	1·174	2·276
	1957–58	38·8	47·0	42·6	43·1	46·5	45·1	41·2	41·2	42·6	43·1	1·679	N.S.
	Mean	43·4	49·9	44·1	45·6	47·4	46·9	39·2	40·5	45·1	45·5	1·754	5·09

Effect of treatments on the yield of straw were similar to their effect on grain yield. Treatments which gave high yield of grain also gave high yield of straw.

Economics

With a view to assess the relative merit of various weed control treatments, the economics was worked out (Table X).

From the data given in Table X, it is seen that net profit under different treatments showed the same trend as the yield. The treatment which gave higher yield also showed better profit. In spite of the high cost, hand-weeding proved economically the best treatment followed by weed control with 1 lb. post-emergence (E) application

TABLE X. COMPARATIVE ECONOMICS OF TREATMENTS PER ACRE (AVERAGE OF 3 YEARS)

Treatments	Yield (md./acre)		Value of the difference over control (Rs.)			Expenditure (Rs.)			Net relative gain (Rs.)
	grain	straw	grain	straw	Total	chemical	labour	Total	
Control									
A	14·2	43·4	..	..	..	..	..	..	..
Cultural									
B	18·0	49·9	53·20	13·00	66·20	..	20·00	20·00	46·20
C	15·1	44·1	12·60	1·40	14·00	..	7·38	7·38	6·62
Post 2,4-*D*									
D	16·4	45·6	30·80	4·40	35·20	1·91	4·00	5·91	29·29
E	16·9	47·4	37·80	8·00	45·80	3·82	4·00	7·82	37·98
F	15·9	46·9	23·80	7·00	30·80	7·64	8·00	15·64	15·16
Cultural + *Post* 2,4-*D*									
G	14·5	39·2	4·20	–8·40	–4·20	1·91	11·38	13·29	–17·49
Pre 2,4-*D*									
H	14·3	40·5	1·40	–5·80	–4·40	1·91	4·00	5·91	–1·51
I	15·8	45·1	22·40	3·40	25·80	3·82	4·00	7·82	17·98
Pre + *Post* 2,4-*D*									
J	16·2	45·5	28·00	4·20	32·20	3·82	8·00	11·82	20·38

1. Value of wheat grain at Rs. 14·00 per maund.
2. Value of straw at Rs. 2·00 per maund.
3. Cost of sodium salt of 2,4-D (80% a.e.) at Rs. 3·04 per lb.
4. (a) Cost of hand-weeding at Rs. 20·00 per acre (10 men at Rs. 2·00 per day)
   (b) Cost of hoeing Rs. 7·38 per acre (Rs. 5·38 for one pair and ploughman and Rs. 2·00 for extra man to hold the cultivator).
   (c) Cost of spraying 2,4-D at Rs. 4·00 per acre (2 men at Rs. 2·00 per day).

of 2,4-D. The difference between net profit under the two treatments (B & E) was Rs. 8·22. This difference was, however, largely due to the higher yield of grain and straw obtained under hand-weeding in 1955-56 (Table IX). In 1956-57 and 1957-58, there being not much difference in yield, the weedicide application was, therefore, more economical in these two years because of its low cost of application. It will also be noted that treatments G and H showed a loss.

DISCUSSION

From the weed population studies of this experiment, it is evident that non-grass weeds form the predominant weed flora of wheat fields.

Hand-weeding gave effective but temporary control of all types of weeds. Besides being laborious and costly it suffered from the disadvantage that quite a large number of weeds reappeared from the fresh weed seeds brought up to the surface soil by this operation. Deeper interculture with a hoe was economically better, but from weed control point of view it proved inferior to hand-weeding. This was partly because weeds in and near the crop rows were not destroyed and partly due to germination of fresh weeds soon after the operation. These weeds though did not compete much with the standing crop yet served as source of weed seed infection for the future years. This later point is clear from the comparatively low residual and cumulative effects of previous year's cultural treatments in 1956-57 and 1957-58 (Table III, I observation). Inferiority of hoeing as a weed control measure was further clear from the fact that dry matter weight of the weed plants from hoed plots was significantly higher than from hand-weeded or 2,4-D treated plots.

Post-emergence application of weedicide overcame all these drawbacks of cultural treatments. Because the weedicide was applied as a 'blanket treatment' all the susceptible weeds whether in or in between the rows were killed. And as the soil was not disturbed practically no reinfestation from fresh weed seeds occurred. This long term advantage of chemical weed control is clear from the data in Table III. Elimination of weeds with post 2,4-D (treatments D, E, F) resulted in comparatively much lower initial infestation (I count) in the 2nd and 3rd year than under hand-weeded and hoed plots.

Another interesting point worthy of note was the delayed action of pre-emergence application of 2,4-D (treatments H and I, Table III). First weed count taken 40 days after pre-emergence application of treatments recorded practically no weed kill but II observation showed very substantial improvement in this respect. It appears that effectiveness of pre-emergence treatments very largely depends upon the moisture status of the soil, as has also been observed by Pathak (1958). Evidently due to lack of moisture in the surface soil the weedicide applied as pre-emergence spray remained inactive till the first irrigation was given 40 days after sowing. This resulted in the resumed activity of the weedicide and, therefore, substantial kill of the weeds. This is further supported by the fact that in the third year of the experiment when there was a light shower soon after the application of pre-emergence application showed good kill of weeds at first count which in the other years was almost completely absent. Obviously pre-emergence application of 2,4-D under the normal weather conditions of wheat areas of India is not a dependable method of weed control.

Marked increase in grain yield under all treatments as compared to unweeded control established the importance of weed control in wheat crop. Improvement in the yield of grain was more or less in proportion to the degree of weed control under different treatments. For instance under treatment C (Hoeing), H and I (pre-emergence 2,4-D) which gave comparatively poor control of weeds, the average grain yields were 15·1, 14·3 and 15·8 md. per acre, respectively, as compared to 18·0 md. under hand-weeding (B) and 16·9 md. under post-emergence 2,4-D at 1 lb. per acre.

It was further noted that 1 lb. post-emergence application of the weedicide gave nearly as good yields as hand-weeding in two out of three years. Lower yield under

this weedicide treatment in the first year was possibly due partly to higher infestation by *Cynodon dactylon* which is not amiable to 2,4-D control and partly to late sowing and, therefore, less of weed competition from other categories of weeds in the hand-weeded plots.

It was also noteworthy that application of 2,4-D soon after hoeing (treatment G), though very successful in weed elimination, had considerable depressing effect on yield. Compared to 14·5 md. under this treatment, application of same dose (½ lb. a.e. per ac.) but without hoeing (D) yielded 16·4 md. of grain per acre. This may be ascribed to the possible injury to the crop by 2,4-D coming in more close contact with roots due to hoeing operation. Roots, as has been pointed out by Crafts and Harvey (1950) are 10 to 100 times more sensitive to 2,4-D than the aerial parts of the plants.

It is also clear that 2 lb. rate of 2,4-D application had adverse effect on the crop. In spite of the fact that best control of weeds was obtained under this treatment, the yield was 15·9 md./acre as compared to 16·9 md. obtained under 1 lb. rate. From another consideration also rate higher than 1 lb. per acre to this crop appears to be unadvisable. It will be noted from the data in Table V, that while most other non-graminaceous weeds were completely killed, two legume weeds *Melilotus parviflora* and *Medicago denticulata* showed fair resistance to 2,4-D up to 1 lb. rate. At 2 lb. they were also eliminated. Visually also this effect was very clear. It is possible that moderate population of legume weeds instead of being harmful, may prove beneficial to the crop because of their ability to fix atmospheric nitrogen with consequent benefit to the crop. This observation, however, would need more detailed study on this aspect before any firm conclusion can be drawn.

This study further showed that increase in yield was not so much related to better growth as indicated by height and production of tillers but was largely the result of increased number of effective tillers and more grain per earhead. This is what could be expected, as the treatments applied at six weeks (after tillering phase was over) could not possibly have much effect on the formation of tillers; but elimination of weed competition at this stage would largely help in maturing more tillers with more grain per earhead. Similar observation was also made by Pande (1954).

How far and how quickly any new practice in crop production will be taken up by the cultivators, will very largely depend on the economics of the new practice as compared to the established method. Other factors such as saving of labour, convenience and ease of operation and the initial cost of treatment will also influence the choice. In the present experiment although handweeding has recorded slightly higher yield and consequently higher profit, these differences in yield during all the three years or in the combined analysis were not significant. When ease of application and low initial investment in weedicide spraying is taken into consideration, it can be stated that control of weeds by post-emergence spraying of 2,4-D at 1 lb. per acre can serve an equally effective alternative to hand weeding.

Hoeing proved an unsound method of weed control than 2,4-D or hand-weeding and, therefore, gave lower yields and consequently economically too it proved very much inferior to hand-weeding and 2,4-D application. Injury to roots of wheat plant was also possibly caused by the interculture operation and this factor may also be to some extent responsible for lower yields in hoed plots.

SUMMARY AND CONCLUSION

This investigation was carried out at the Division of Agronomy, Indian Agricultural Research Institute, New Delhi, during the years 1955-56 to 1957-58 to study the comparative efficacy of pre- and post-emergence application of 2,4-D (sodium salt at ½, 1 and 2 lb. a.e. per acre), hand-weeding and interculture for controlling weeds in wheat crop. The results showed that:

1. Post-emergence application of sodium salt of 2,4-D at one pound a.e. per acre proved most effective for the control of weeds (except grasses) and gave significantly (19·0 per cent) higher yield than control.

2. Hand-weeding was less effective for weed control than weedicide application, but gave the highest yield (26·7 per cent higher than control). The difference between hand-weeding and 2,4-D post-emergence application at one pound rate were, however, not significant.

3. Intercultivation by bullocks and pre-emergence application of 2,4-D proved unsatisfactory both from the point of view of control of weeds and the increase in yield.

4. The leguminous weeds like *Melilotus parviflora* and *Medicago denticulata* appeared to be more tolerant of 2,4-D application up to one pound a.e. than other broad-leaved weeds, such as *Chenopodium album*, *Heliotropium eithwaldii*, *Carthamus oxyacantha*. At two-pound rate, both categories of weeds were almost completely destroyed.

5. Economically 2,4-D post-emergence application at one pound a.e. was almost as good as hand-weeding.

On the basis of this investigation, it can be concluded that post-emergence application of 2,4-D (sodium salt) at one pound a.e. gives better control of weeds than hand-weeding and can successfully replace hand-weeding particularly where there is shortage of labour and or wages are high. For large wheat areas, weeding by 2,4-D is indispensable.

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DECOMPOSITION OF ORGANIC MATTER AS AFFECTED BY PHOSPHORUS

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PHOSPHORUS plays a significant role in the decomposition of organic matter in soil. In the previous communication, Gangwar and Pathak (1959) observed increased availability of phosphorus as a result of decomposition of organic matter in soil and since the decomposition of organic matter in soil is a function of soil microorganisms, an effort has, therefore, been made to assess the role of phosphorus in its decomposition in soil.

Whiting and Heck (1926) suggested that during decomposition of carbonaceous material, phosphorus might be of advantage. Shrikhande (1948) recognizing the importance of phosphorus during decomposition of organic matter, derived ' phosphorus factor ' as one-fifth of ' nitrogen factor '. Wallunjkar and Acharya (1954) observed beneficial effect of phosphorus on cattle dung, when applied to soil. Acharya and Jha (1954) observed that bacterial counts, rate of CO_2 evolution, ammonification, nitrification and nitrogen fixation, were increased in soil on application of phosphatic fertilizers. Recent findings of Bishwas *et al.* (1957) revealed that rate of CO_2 evolution, ammonification and nitrification in mustard cake-treated soil were increased in combination with superphosphate. Thompson *et al.* (1931), Richards and Srikhande (1935) and Shrikhande and Yadav (1953) have shown that phosphorus in various forms, up to a certain concentration was required for the growth of *Azotobacter*, which stimulated the nitrogen fixation. Dhar (1937) observed a greater fixation of atmospheric nitrogen in the presence of phosphorus in composting of cowdung, wheat straw or sawdust. He (1956) further reported that the phosphorus content of bacteria and fungi are high, hence they multiply readily in the presence of soluble phosphorus and consequently accelerate the fixation of atmospheric nitrogen in soil by decomposing all types of organic matter, but ferric and aluminium phosphates are much inferior to calcium phosphate. Recently he (1959) reported that the addition of different types of calcium phosphate to nitrogenous compounds undergoing nitrification reduced the loss of nitrogen.

MATERIAL AND METHODS

Plan of investigation: A surface soil sample was collected from the cultivated field of the student's Instructional Farm, Government Agricultural College, Kanpur. *Sanai*, *moong* T_1 and mustard cake were added in the soil on the nitrogen basis supplying 0·025 per cent nitrogen. Phosphorus as single superphosphate, di-calcium phosphate and ferric phosphate were added supplying 0·1 per cent P_2O_5. The experiment was conducted in beakers with four replications under controlled laboratory

conditions where optimum temperature and moisture conditions were maintained. Temperature was maintained at 30°C and moisture was maintained at 50 per cent of its water holding capacity.

Data incorporated in the paper are the mean of the four replications. Data in Table I give the chemical composition of the soil and sources of organic matter used.

TABLE I. CHEMICAL COMPOSITION OF SOIL AND DIFFERENT SOURCES OF ORGANIC MATTER

Samples	Organic carbon %	Total nitrogen %	C/N	Phosphorus %	NH_4-N in p.p.m.	NO_3-N in p.p.m.
Soil	0·45	0·043	10·46	0·059	6·11	10·50
Sanai	60·80	3·00	20·26	0·300	..	..
Moong T_1	59·00	2·55	23·14	0·290	..	..
Mustard cake	52·80	5·62	9·70	0·410	..	..

Method of analysis: Organic carbon was estimated by Walkley and Black (1934) method; total nitrogen was determined by the standard Kjeldahl method as modified by Bal (1925); total phosphorus was determined in the HCl extract of the soil following A.O.A.C. (1955) method; ammoniacal nitrogen was estimated following Richardson (1938) method as described by Piper (1950); nitrate nitrogen was determined by Harper's (1924) phenol di-sulphonic acid method.

RESULTS AND DISCUSSION

A persual of the data given in Table II indicated a greater loss of organic carbon in phosphorus treated than in untreated soils. It is also observed that superphosphate induced greater loss of organic matter than di-calcium phosphate or ferric phosphate. Of the sources of organic matter, *moong* showed greater loss of organic carbon than *sanai* or cake. This correlates positively with C/N ratio of different organic matters (Table I).

There was a slight increase in the total nitrogen content of phosphorus-treated soils over untreated ones, which may be attributed to the increased activity of *Azotobacter*. This has also been observed by Dzierzbickii (1910), Waksman (1932), Pathak (1954) and Biswas (1957). This activity was observed greater in superphosphate treated soil than in the other two sources of phosphorus. Dhar (1956) has also observed little effect of aluminium and iron phosphates on nitrogen fixation. There had been a gradual decrease in C/N ratios in all the treatments which was more pronounced in phosphorus-treated ones in which superphosphate showed the highest effect followed by di-calcium phosphate and ferric phosphate. Of the organic matters studied, *sanai* showed the highest effect and the oil-cake the least, which may be corroborated with the findings of Turk and Millar (1936) who observed less loss of carbon with narrow C/N ratio and more with the wider C/N ratio.

As indicated from the data in Table III, phosphorus has a marked effect on ammonification and nitrification. There was a significant increase in the rate of

TABLE II. ORGANIC CARBON, TOTAL NITROGEN AND C/N RATIO

Treatments	Carbon percentage					Nitrogen percentage					C/N				
	At start	At 20 days	At 40 days	At 60 days	At 80 days	At start	At 20 days	At 40 days	At 60 days	At 80 days	At start	At 20 days	At 40 days	At 60 days	At 80 days
Soil (control)	0·45	0·44	0·43	0·42	0·40	0·0430	0·0430	0·0430	0·0410	0·0420	10·46	10·23	10·00	10·00	9·50
Soil+*Sanai*	1·16	1·04	0·90	0·82	0·70	0·0680	0·0682	0·0684	0·0685	0·0687	17·06	15·20	13·10	11·83	10·20
Soil+*Sanai*+superphosphate	1·16	0·94	0·80	0·70	0·64	0·0680	0·0683	0·0686	0·0690	0·0720	17·06	13·80	11·70	10·10	9·00
Soil+*Sanai*+di-calcium phosphate	1·16	1·00	0·82	0·75	0·64	0·0680	0·0682	0·0686	0·0690	0·0714	17·06	14·68	12·06	10·87	9·10
Soil+*Sanai*+ferric phosphate	1·16	1·01	0·90	0·80	0·69	0·0680	0·0680	0·0680	0·0685	0·0686	17 06	14·90	13·20	11·83	10·00
Soil+*Moong*	1·30	1·13	0·93	0·81	0·76	0·0680	0·0681	0·0623	0·0685	0·0688	19·13	16·60	13·60	11·86	11·00
Soil+*Moong*+superphosphate	1·30	0·91	0·81	0·70	0·65	0·0680	0·0683	0·0690	0·0692	0·0722	19·13	14·00	11·75	10·15	9·00
Soil+*Moong*+di-calcium phosphate	1·30	0·98	0·85	0·72	0·66	0·0680	0·0682	0·0688	0·0692	0·0718	19·13	14·57	12·40	11·40	9·18
Soil+*Moong*+ferric phosphate	1·30	1·00	0·90	0·80	0·68	0·0680	0·0680	0·0684	0·0686	0·0688	19·13	14·70	13·10	11·66	9·90
Soil+Mustard cake	0·92	0·89	0·78	0·70	0·67	0·0680	0·0680	0·0670	0·0668	0·0690	13·53	13·10	11·64	10·64	9·80
Soil+Mustard cake+superphosphate	0·92	0·79	0·70	0·62	0·54	0·0680	0·0681	0·0682	0·0688	0·0690	13·53	11·60	10·23	9·00	8·00
Soil+Mustard cake+di-calcium phosphate	0·92	0·80	0·72	0·66	0·55	0·0680	0·0680	0·0681	0·0688	0·0690	13·53	11·77	10·60	9·50	8·00
Soil+Mustard cake+ferric phosphate	0·92	0·88	0·76	0·69	0·59	0·0680	0·0680	0·0678	0·0672	0·0672	13·53	12·90	11·50	10·25	9·00

TABLE III. AMMONIACAL AND NITRATE NITROGEN

Treatments	Ammoniacal nitrogen (in ppm.)					Nitrate nitrgoen (in ppm.)				
	At start	At 20 days	At 40 days	At 60 days	At 80 days	At start	At 20 days	At 40 days	At 60 days	At 80 days
Soil (control)	6·11	10·50	12·80	8·85	8·00	10·50	14·10	16·31	28·90	22·50
Soil + *Sanai*	6·30	23·13	56·12	60·30	20·17	10·50	12·50	88·60	104·00	135·50
Soil+*Sanai*+superphosphate	6·30	35·10	88·70	80·50	39·20	10·50	11·80	124·80	160·00	200·30
Soil+*Sanai*+di-calcium phosphate	6·30	29·92	81·50	75·10	40·00	10·50	12·00	115·40	149·35	192·00
Soil+*Sanai*+ferric phosphate	6·30	24·00	72·30	60·75	29·50	10·50	10·90	99·50	128·80	166·90
Soil+*Moong*	6·50	18·85	39·20	43·70	28·60	10·50	9·00	49·60	108·54	128·00
Soil+*Moong*+superphosphate	6·50	24·32	76·43	70·13	25·82	10·50	9·00	73·50	140·80	190·10
Soil+*Moong*+di-calcium phosphate	6·50	24·40	70·83	65·35	23·00	10·50	7·30	65·50	135·75	185·70
Soil+*Moong*+ferric phosphate	6·50	20·90	58·00	52·00	20·80	10·50	8·00	50·15	126·20	164·82
Soil+Mustard cake	6·20	13·80	16·00	45·60	40·00	10·50	12·50	35·05	69·82	80·50
Soil+Mustard cake+superphosphate	6·20	16·85	29·50	65·90	60·00	10·50	13·15	84·00	135·80	150·37
Soil+Mustard cake+di-calcium phosphate	6·20	16·00	27·80	62·00	51·30	10·50	12·94	80·40	130·75	143·50
Soil+Mustard cake+ferric phosphate	6·20	16·00	21·50	56·00	48·00	10·50	10·10	43·20	91·00	95·15

ammonification in phosphorus-treated soils. In phosphorus-treated soils, the maximum ammonia accumulation was found on the 40th day, after which there was a tendency to decline, while in untreated soils the ammonification was found maximum on the 60th day. This is obvious as phosphorus accelerates the decomposition of organic matter by increasing the rate of humification and nitrification. The nitrification data indicated only a slight increase in the nitrate content on the 20th day of incubation. This increase in all the treatments was less than the control itself which indicates that there was nitrate depression in soils treated with organic matter, which may be attributed to the assimilation of nitrate-nitrogen by the increased activity of microorganisms. Hibbard (1919), Martin (1925), Blair and Prince (1928), Allison (1927) and Hutchinson (1934) have also observed intense activity of general purpose decay organisms, utilizing available nitrogen rather than appearing as Nitrate. Phosphorus-treated organic matter showed greatest nitrifying power than the untreated one. The superphosphate and di-calcium phosphate-treated soils showed greater nitrification than the ferric phosphate treated soils. This may be attributed to the beneficial effect of calcium, firstly by neutralizing the acid produced during nitrification and secondly

by the increased activity of bacteria stimulated by the phosphorus itself. Of the different sources of organic matters, *sanai* showed the highest ammonification and nitrification, while mustard cake, though containing as high as 5·6 per cent total nitrogen, showed the least, which may be attributed to the fat content of cake which retards nitrification as observed by Shrikhande (1945).

SUMMARY

The soil was treated with *sanai*, *moong* T_1 and mustard cake supplying 0·025 per cent nitrogen and single superphosphate, di-calcium phosphate and ferric phosphate supplying 0·1 per cent P_2O_5. It was found that (a) phosphorus-treated organic matter showed a rapid loss of organic carbon; (b) there was a slight gain in the value of total nitrogen in soil treated with organic matter and phosphorus over the treatments without phosphorus; (c) supplying the different sources of organic matter on equal nitrogen basis *moong* T_1 showed the widest C/N ratio followed by *sanai* and mustard cake; (d) phosphorus-treated organic matter showed a faster and greater ammonification and nitrification than the untreated ones; (e) of the different sources of organic matter *sanai* showed better results than *moong* T_1 or oil-cake; and (f) of the different sources of phosphorus, superphosphate showed better results than di-calcium phosphate or ferric phosphate.

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NITROGEN FIXATION BY *STIGONEMA DENDROIDEUM* FRÉMY*

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THE hitherto available information, with few exceptions, shows that among Myxophyceae, the capacity to fix atmospheric nitrogen is largely confined to a single family, Nostocaceae. Singh (1942) reported that *Aulosira fertilissima* was able to fix nitrogen. This genus was placed in the family Microchaetaceae by Geitler (1932) although Fritsch (1945) and Desikachary (1959) considered it to be most appropriately included in the Nostocaceae. The members belonging to the Oscillatoriaceae, said to possess this capacity, have not been conclusively shown to be capable of fixing nitrogen (Copeland, 1932; Odintzoa, 1941). *Tolypothrix tenuis*, belonging to the Scytonemataceae and *Calothrix brevissima*, belonging to the Rivulariaceae, have also been shown to fix nitrogen (Watanabe, 1951). Recently, Mr. P. Fai, using the method similar to that of Fogg (1951) has demonstrated that the Chroococcalean member, *Chloroglea fritschii* is able to fix atmopsheric nitrogen (Fogg, 1959), whereas seven other species of unicellular Chroococcales have been found to be incapable of fixing nitrogen (Fogg and Wolfe, 1954). Fogg (1951) demonstrated that the hot spring alga, *Mastigocladus laminosus*, belonging to the Stigonematales, was able to fix nitrogen. The present investigation on another Stigonematalean member, *Stigonema dendroideum* adds one more member to the group of nitrogen-fixing blue-green algae.

EXPERIMENTAL METHODS

During the studies on soil algae of the cultivated and uncultivated soils inside the Indian Agricultural Research Institute grounds, the blue-green alga, *Stigonema dendroideum*, came up abundantly in all the soil samples from the uncultivated soils (Dutta and Venkataraman, 1958). The chemical analyses of the soil samples, in which the alga came up, are given in Table I.

TABLE I. CHEMICAL ANALYSES OF THE SOIL SAMPLES

pH	% organic carbon	Total organic matter	% exchangeable calcium	% total nitrogen
8·05–8·2	0·35–0·4	0·602–0·688	5·6–7·0	0·0014–0·0546

The alga was isolated by repeated dilution cultures on silica gel plates enriched with nitrogen-free medium and later maintained in Erlenmeyer flasks under identical

*Part of the thesis approved for the Ph.D. Degree of the Banaras Hindu University.

conditions. The medium used was that of Fogg (1949) with the addition of 0·2 gm. sodium bicarbonate per litre (Fogg, 1951). The pH of the medium was 8-8·2. Bacteria-free cultures were obtained by ultra-violet irradiation for three to four minutes (Bortles, 1940; Henriksson, 1951; Venkataraman *et at.*, 1959). Bacterial tests were made on the following media (Henriksson, 1951):

1. Media containing 0·5 per cent dextrose, 0·2 per cent yeast-extract and 0·2 per cent bacteriological peptone;
2. in sucrose-nitrate-soil extract liquid and solid media (De, 1939);
3. on media containing Bactocasamino acids 0·05 per cent, peptone 0·05 per cent, starch 0·05 per cent, K_2HPO_4 0·05 per cent and agar 1·5 per cent;
4. on medium 77 according to Fredman and Waksman(1928); and
5. on Brewer's medium.

Dry weight determinations were made on algal material sedimented by centrifugation and washed twice by resuspension in redistilled water, followed by centrifugation and drying to a constant weight at 60°C. The yields from three flasks were placed in one weighing bottle to provide sufficient material for an accurate dry weight determination. The values reported are the means with their standard deviations based upon the results of three determinations, using a correction value for the salts.

Nitrogen estimations were done by the conventional micro-Kjeldahl method. When the contents of the culture flasks were to be analysed, the alga was detached from the sides of the vessel by means of a rubber-tipped glass rod and the alga and the medium were separated by centrifuging at about 3,000 r.p.m. The alga was washed once with sterile distilled water and the washings were added to the medium. The nitrogen in the medium and in the alga were estimated separately. The analyses were made 20 days after the date of inoculation. Control analyses of uninoculated flasks did not give any measurable values of nitrogen.

RESULTS

The results are given in Table II. The mean net fixation after 20 days' growth was $3·24 \pm 0·18$ mg. N per 100 ml. of the medium and the total growth of the alga during the same period in terms of dry weight was $49·32 \pm 0·6884$ mg./300 ml. of the medium. The percentage of extracellular nitrogen liberated by the alga into the medium was $26·2 \pm 0·81$.

TABLE II. NITROGEN FIXATION BY *STIGONEMA DENDROIDEUM* IN NITROGEN-FREE MEDIUM (NITROGEN IN MG./100 ML.; CULTURES ANALYSED AFTER 20 DAYS; VALUES ARE THE MEANS WITH THEIR STANDARD DEVIATION BASED ON THREE DETERMINATIONS)

	Total N	Intracellular N	Extracellular N
1	$3·73 \pm 0·46$	$2·71 \pm 0·38$	$0·98 \pm 0·11$
2	$3·06 \pm 0·26$	$2·18 \pm 0·42$	$0·83 \pm 0·23$
3	$2·94 \pm 0·44$	$2·18 \pm 0·49$	$0·75 \pm 0·11$
Mean of triplicate means	$3·24 \pm 0·18$	$2·35 \pm 0·29$	$0·85 \pm 0·35$

SUMMARY

The Stigonematalean member, *Stigonema dendroideum*, has been shown to be capable of fixing atmospheric nitrogen. About a fourth of total nitrogen fixed is given off into the medium.

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EFFECT OF VARIOUS CONCENTRATIONS OF GIBBERELLIN ON GROWTH, FLOWERS, FRUITS, MINERAL COMPOSITION AND MINERAL UPTAKE OF TOMATO PLANTS

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WITHIN the last few years intensive studies on practical uses of gibberellin, a potent plant growth increasing compound discovered by Japanese scientists, has begun. It was thought advisable to determine its influence on growth, flowers, fruits, mineral composition and mineral uptake of tomato plants.

MATERIAL AND METHODS

Tomato seeds, variety John Baer, were sown in flats on October 1, 1957 in the Plant Science Greenhouse of the University (average temperature of 60°F and average day length of 10·42 hours). The seedlings were transplanted on October 29, 1957 in eight-inch pots containing medium grade quartz sand.

Each plant after transplantation received a pint (0·125 gal.) of Hoagland and Arnon's (1950) nutrient solution and one quart (2 pints) of water every alternate day until January 1, 1958, after which the additions of nutrient solutions were increased to one quart per plant, while the amount of water added was the same for the entire duration of the experiment.

Foliar application of potassium gibberellate in concentrations of 100, 250 and 500 p.p.m. were used for the experiment.

The entire gibberellin experiment was conducted in two parts—first part with growth, flowering and fruiting and the second with weight, mineral composition and mineral uptake of tomato plants.

Out of these plants a lot of 32 plants of uniform height was selected for growth, flowering and fruiting studies. Later a sub-group of eight plants was used for each concentration of gibberellin, i.e., check, 100, 250 and 500 p.p.m. received on December 24, 1957. These plants were randomized with eight replications of four treatments. Periodic observations were recorded for general observations, height, stem-diameter, number of leaves, size of the largest leaf, number of laterals, number of flowers and number of fruits.

The rest of the potted plants were classified into three groups, i.e., large, medium and small on the basis of their height. These plants also received gibberellin in different concentrations. These plants were randomized with three replications (each replication consisted of three plants, i.e., large, medium and small), three harvest dates (i.e., one week, three weeks and six weeks period after the application date of the compounds), and four treatments. The data were recorded for fresh and dry weight of the tops and the roots, and the per cent composition on the dry weight basis of the plant.

Nitrogen was determined by standard Kjeldahl's method and potassium by flame-photometer, while phosphorus, calcium, magnesium, iron, boron, manganese, copper and zinc were determined spectrographically (A.O.A.C. 1955).

The mineral accumulation figures for each element were obtained by the following formula:

$$\text{Total amount of each mineral per plant} = \frac{\text{Average dry weight per plant} \times \text{Average per cent of the mineral present}}{100}$$

Difference between the amount of mineral content present in plants on any two dates was considered as the amount of mineral uptake for that duration.

EXPERIMENTAL RESULTS

All the measurements and mineral determination have been recorded periodically and statistical analyses were carried out. The averages and the least significant differences (L.S.D.) were calculated and given in Tables.

General observations: The general observations on the plants were also recorded. Differences in sizes of plants could be clearly seen after the first week of the treatment. Plant growth increased with the increase in concentration of gibberellin applied.

A very characteristic symptom was noticed in all the treated plants. Small patches appeared on basal leaves of the treated plants after the first week of treatment. By third week, these patches became slightly bigger and white in colour showing the absence of chlorophyll in these regions. This leaf pattern was only confined to few of the basal leaves. The new growth did not show any sign of white patches in leaves.

The gibberellin treated plants exhibited chlorosis on the lower 10 to 12 leaves of plants after three weeks of the treatment. Chlorosis became progressively more intense with increase of time interval. Chlorosis was also confined to lower 10 to 12 leaves.

Fruits set in checks were earlier than the treated plants although the flowering started practically at the same time. Number of fruits was greater in check plants than in treated plants. The fruits also ripened earlier in check than treated plants. Ripe fruits on treated plants showed a peculiar russetting and malformation. In general, fruits on treated plants were smaller than on check but with fewer seeds.

Growth, flowers and fruits: The averages and the least significant differences (L.S.D.) calculated from the periodic measurements have been recorded in Table I.

It is clearly seen that the significant differences between treatments existed in all the measurements except for size of the largest leaf and the number of flowers.

The height of plants showed that 250 and 500 p.p.m. treated plants were significantly taller than checks. No significant differences were found between 100 p.p.m. treated plants and checks; 250 and 500 p.p.m. treated plants or between 100 and 250 p.p.m. treated plants.

A significantly greater diameter of stem was found in 500 p.p.m. treated plants than checks. No significant differences were found between checks and 100 or 250 p.p.m. treated plants.

TABLE I. EFFECT OF VARIOUS CONCENTRATIONS OF GIBBERELLIN ON GROWTH, FLOWERS AND FRUITS OF TOMATO PLANTS

Measurements	Treatments				L.S.D. for treatments	
	Check	100 p.p.m.	250 p.p.m.	500 p.p.m.	5%	1%
Height† (cm.)	62·1	65·2	68·6	72·3	4·9	6·6
Stem† diameter (cm.)	6·14	6·06	6·42	6·76	0·43	0·58
Number† of leaves	22·00	23·8	25·8	26·7	2·6	3·6
Size† of the largest leaf (cm.)	32·5	32·4	33·3	33·5	N.S.	N.S.
Number* of laterals	2·55	3·17	3·30	3·86	0·87	N.S.
Number* of flowers	20·7	21·7	24·1	23·7	N.S.	N.S.
Number‡ of fruits	4·61	2·25	2·70	2·45	0·93	1·26

*All values are averages from 5 observations of 8 replicates.
†All values are averages from 7 observations of 8 replicates.
‡All values are averages from 8 observations of 8 replicates.
N.S.—Statistically not significant.

A significant increase in number of leaves was found in both 250 and 500 p.p.m. treated plants than check. No significant differences existed between check and 100 p.p.m. treated plants and also between 250 and 500 p.p.m. treated plants.

Statistical comparison of individual treatments for number of laterals showed that only 500 p.p.m. treated plants and significantly greater number of laterals per plant than check.

Number of fruits per plant in different treatments showed that all the treated plants bore significantly fewer fruits than check and no significant difference existed among the treated plants.

Fresh and dry weights of tops and roots: The averages and the least significant differences (L.S.D.) were calculated from the periodic measurements for fresh and dry weights of tops and roots per plant and have been recorded in Table II.

TABLE II. EFFECT OF VARIOUS CONCENTRATIONS OF GIBBERELLIN ON FRESH AND DRY WEIGHT OF TOPS AND ROOTS OF TOMATO PLANTS

Measurements (gm.)	*Treatments				L.S.D. for treatments	
	Check	100 p.p.m.	250 p.p.m.	500 p.p.m.	3%	1%
Fresh tops	93·98	96·76	109·52	105·65	5·23	9·94
Fresh roots	28·39	29·66	29·75	25·77	N.S.	N.S.
Dry Tops	9·23	9·15	10·32	9·80	N.S.	N.S.
Dry roots	2·24	2·86	2·67	2·57	0·33	0·45

*All values are averages from 3 observations of 3 replicates.
N.S.—Statistically not significant.

The statistical comparison of individual treatments showed that a significant increase in fresh weight of top was found in both 250 and 500 p.p.m. treated plants than check and 100 p.p.m. treated plants. No significant differences were found between check and 100 p.p.m. treated plants and also between 250 and 500 p.p.m. treated plants.

No significant differences existed between individual treatments in weights of fresh roots and dry tops.

In weights of dry roots per plant, a significant increase in weights of dry roots in all treated plants were found than checks. No significant differences existed between the individual treated plants.

Fresh and dry weights, amount of moisture and per cent moisture: The fresh and dry weights, amount of moisture present and the per cent moisture content per plant for different dates were calculated and have been recorded (Table III).

TABLE III. EFFECT OF VARIOUS CONCENTRATIONS OF GIBBERELLIN ON AVERAGE FRESH AND DRY WEIGHTS, AMOUNT OF MOISTURE, AND PER CENT MOISTURE ON DIFFERENT DATES PER TOMATO PLANT

Dates and treatments	Weight in grams per plant			Per cent moisture
	Fresh	Dry	Moisture	
24–12–1957				
Check	21·73	1·69	20·04	92·2
31–12–1957				
Check	39·65	3·57	36·08	90·9
100 p.p.m.	38·95	3·04	35·91	92·3
250 p.p.m.	46·53	3·85	42·68	91·7
500 p.p.m.	37·42	3·01	34·41	91·9
14–1–1958				
Check	90·78	9·39	81·39	89·6
100 p.p.m.	93·40	9·44	83·96	89·8
250 p.p.m.	93·07	9·12	83·95	90·2
500 p.p.m.	83·86	8·73	75·13	89·6
4–2–1958				
Check	237·93	21·44	216·49	90·9
100 p.p.m.	249·83	23·55	226·28	90·6
250 p.p.m.	278·85	25·97	252·88	90·7
500 p.p.m.	275·84	25·40	250·44	90·4

All observations are average of three replicates.

From the observations of December 31, 1957, it is seen that the plants treated with 250 p.p.m. only showed an increase in fresh and dry weights and also in the amount of moisture present per plant than check plants, whereas plants treated with 100 and 500 p.p.m. showed a decrease in fresh and dry weights and also in the amount of moisture present than check plants. The values for per cent moisture present in different treatments showed a higher moisture per cent in treated plants than checks.

On January 14, 1958, it indicated increase in fresh and dry weights and moisture present per plant in 100 p.p.m. and 250 p.p.m. treatments than check whereas 500 p.p.m. treated plants showed decrease in weights. The moisture per cent for each treatment, however, did not indicate any variation.

The observations of February 4, 1958, indicated an increase in fresh and dry weights and also of moisture content of all the treated plants than checks, whereas no differences existed between individual treatments for per cent moisture content.

Mineral composition: The plant analyses were carried out for ten mineral elements at three different stages of growth. The averages were calculated and recorded (Table IV).

TABLE IV. EFFECT OF VARIOUS CONCENTRATIONS OF GIBBERELLIN ON PER CENT MINERAL COMPOSITION OF TOMATO PLANTS

Minerals	*Treatments				L.S.D. for treatments	
	Check	100 p.p.m.	250 p.p.m.	500 p.p.m.	5%	1%
Nitrogen	3·47	3·45	3·46	3·49	N.S.	N.S.
Phosphorus	0·17	0·16	0·16	0·16	N.S.	N.S.
Potassium	5·07	5·31	5·44	5·67	0·06	0·09
Calcium	2·99	2·99	2·92	2·89	N.S.	N.S.
Magnesium	0·65	0·66	0·65	0·64	N.S.	N.S.
Iron	0·0375	0·0271	0·0326	0·0302	0·0023	0·0031
Boron	0·0031	0·0029	0·0033	0·0028	N.S.	N.S.
Manganese	0·0038	0·0033	0·0034	0·0032	0·0002	0·0003
Copper	0·0025	0·0026	0·0029	0·0025	N.S.	N.S.
Zinc	0·0059	0·0056	0·0063	0·0067	N.S.	N.S.

*All values are averages from 3 observations of 3 replicates.
N.S.—Statistically not significant.

The whole data was statistically analysed. Significant differences between individual treatments for percentage of various mineral elements present, were only found in potassium, iron and manganese.

A significantly higher percentage of potassium and a lower percentage of iron and manganese were found in treated plants than check.

From the data (Table V), for average percentage of potassium, iron and manganese present at different stages of growth, it can be clearly seen that the various concentrations of gibberellin had a pronounced effect on the plant composition.

TABLE V. EFFECT OF VARIOUS CONCENTRATIONS OF GIBBERELLIN ON AVERAGE PERCENTAGE OF POTASSIUM, IRON AND MANGANESE PRESENT AT DIFFERENT DATES IN TOMATO PLANTS

Dates and treatments	Minerals/Dry weight (per cent)		
	Potassium	Iron	Manganese
Dec. 24, 1957			
Check	5·52	0·0292	0·0038
Dec. 31, 1957			
Check	5·73	0·0378	0·0046
100 p.p.m.	6·14	0·0269	0·0035
250 p.p.m.	6·16	0·0350	0·0036
500 p.p.m.	6·99	0·0310	0·0032
Jan. 14, 1958			
Check	4·89	0·0364	0·0032
100 p.p.m.	5·05	0·0360	0·0035
250 p.p.m.	5·20	0·0360	0·0034
500 p.p.m.	5·22	0·0322	0·0031
Feb. 4, 1958			
Check	4·59	0·0383	0·0036
100 p.p.m.	4·74	0·0185	0·0028
250 p.p.m.	4·96	0·0267	0·0031
500 p.p.m.	4·81	0·0275	0·0032

All values are averages from three replicates.

The analyses of plants, one week after gibberellin application showed a higher percentage of potassium and lower percentages of iron and manganese present in the treated plants as compared to checks.

Data for potassium clearly indicate that the earlier differences between the check and the various concentrations of gibberellin treatment remain practically similar at all stages, whereas, in case of iron, these differences increased with increase in time. The data for manganese, however, indicated that the differences are minimised with the increase in time.

Mineral uptake: The average uptake for each of the ten mineral elements during the period of experiment were calculated and recorded (Table VI).

TABLE VI. EFFECT OF VARIOUS CONCENTRATIONS OF GIBBERELLIN ON MINERAL UPTAKE OF TOMATO PLANTS

Minerals	*Treatments				L.S.D. for treatments	
	Check	100 p.p.m.	250 p.p.m.	500 p.p.m.	5%	1%
Nitrogen (mg.)	197	218	237	224	N.S.	N.S.
Phosphorus (mg.)	10	11	12	11	N.S.	N.S.
Potassium (mg.)	297	341	399	376	45·1	61·5
Calcium (mg.)	213	218	236	195	N.S.	N.S.
Magnesium (mg.)	45	50	50	51	N.S.	N.S.
Iron (mg.)	2·6	1·3	2·1	2·1	0·4	0·6
Boron (μg.)	272	247	300	238	36·8	50·2
Manganese (μg.)	234	195	247	249	37·3	50·8
Copper (μg.)	199	207	291	179	62·1	84·6
Zinc (μg.)	361	296	427	408	N.S.	N.S.

*All values are averages from 3 observations of 3 replicates.
N.S.—Statistically not significant.

Significant differences as a result of treatments were found only in potassium, iron, boron, manganese and copper.

From the statistical comparison of individual treatments for the uptake of potassium, a significantly higher amount was found in all treated plants, as compared to checks, excepting for 100 p.p.m. treated plants, whereas no significant differences existed. Significant differences were neither found between 100 and 500 p.p.m. treated plants, nor between 250 and 500 p.p.m. treated plants.

The data for uptake of iron showed that all treated plants had significantly lower amounts of iron than check. No significant differences were found between 250 and 500 p.p.m. treated plants. A significant increase in the amount of iron was found in both 250 and 500 p.p.m. treated plants over 100 p.p.m. treated plants.

No significant differences existed in the uptake of boron excepting for 250 p.p.m. treated plants which showed a higher amount of boron than both 100 and 500 p.p.m. treated plants.

The uptake of manganese did not show any significant differences between treatments excepting for 100 p.p.m. treated plants, which had a significantly lower uptake of manganese than the rest of the treatments.

In copper, only 250 p.p.m. treated plants had a significantly higher uptake than all the other treatments.

DISCUSSION

In the recent years there has been a great interest among horticulturists, agronomists and plant physiologists on stimulation of growth resulting from gibberellin application. Accordingly experiments were arranged to find some information on growth and mineral content of tomato plants as affected by this compound.

The data indicated (Table I) that growth of plants increased with an increase in the concentration of gibberellin applied. Similar increase in growth of various plants have also been reported by Marth *et al.* (1956); Chardon (1956); Bukovac and Wittwer (1956); and Gray (1956).

Fresh weights of treated plants, tops only, were significantly greater than the check plants (Table II). However, no significant differences in their dry weights were observed, showing that differences existed only in their water content. Kato (1956) pointed out that elongation and water uptake of pea sections was markedly increased by gibberellin treatments, a fact which is substantiated by the result of this experiment.

From the data (Table III), it is concluded that, although application of various concentrations of gibberellin may result in differences in growth intensity in tomato plants, nevertheless, the fresh and dry weights and the moisture content per treated plant increased with increase in time than the check plants, whereas the increased moisture percentage prevailing earlier in the gibberellin-treated plants ceases to be an influence with increase in time.

Such an increase in growth on account of gibberellin treatment has also been reported by Kurosawa (1932) in rice seedlings, who suggested potassium as an essential element in its elongation. Results of these investigations reported herein also showed that per cent and total accumulation of potassium was increased by gibberellin treatments (Tables IV, V and VI). Similar increase in potassium has also been found by Brian *et al.* (1954) in both wheat and peas. It is suggested that the increased growth in gibberellin-treated plants may precisely be due to a greater uptake of potassium and water.

Periodic observations indicated a decreased number of fruits on gibberellin-treated plants (Table I) with a peculiar russetting and malformation on the ripe fruits as has been reported by Wittwer and Bukovac (1957) in tomato fruits. It is suggested that deficiency of iron and manganese (Table V) caused by gibberellin treatment may be responsible for less fruit set and also for russetting and malformation of ripe tomato fruits.

Induction of parthenocarpic fruits in tomato has been reported by Rappaport (1957) and Wittwer *et al.* (1957) after the application of gibberellin. The results of this experiment also showed fewer seeds in fruits of treated plants.

The total dry weight of the treated plants exhibited, after six weeks from the date of application of gibberellin, an increase over the check plants. Such an increase in total dry weight are in conformity with the findings of Brian *et al.* (1954). It is logical to assume that this increased dry weight of gibberellin-treated plants may be due to higher accumulation of various minerals (Table VI).

Visual observations indicated chlorosis and white patches of the leaves of the gibberellin-treated plants. However, Kato (1951) reported that he could not find

this chloratic condition in the case of plants grown in nutrient solution containing gibberellin, although opposing views have been expressed by Morgan and Mees (1956) and various other research workers who described this chloratic condition of the gibberellin-treated plants due to nitrogen deficiency.

Under the condition of this experiment no significant differences between treatments either in the per cent or the total uptake of nitrogen, were found. On the other hand, significant decrease in both per cent iron and manganese were found as a result of gibberellin treatments (Table IV and VI). Therefore, it is quite probable that lack of iron and/or manganese may be involved in the appearance of chlorosis and white patches on the leaves of gibberellin-treated plant.

SUMMARY

Growth increased in all gibberellin-treated tomato plants. Plants treated with 250 and 500 p.p.m. showed more increase in growth than 100 p.p.m. treated ones. The increase of growth in treated plants was perhaps due to a greater uptake of potassium and water.

In the size of the largest leaf and number of flowers, no significant differences existed between the treatments. In treated plants the number of fruits set was delayed and less in number. Size of the ripened fruits were smaller with fewer seeds.

Leaves of the gibberellin-treated plants showed chlorosis and white patches. The ripened fruits showed a peculiar russetting and malformation. These may be due to the deficiency of iron and/or manganese.

The total weight of treated plants was also increased showing a higher total uptake of all the minerals except iron. A higher percentage of potassium and lower percentage of iron and manganese content existed in treated plants as compared to check plants.

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REVIEWS

Principles and Procedures of Statistics. By Steel and Torrie (McGraw-Hill Book Co. 1960). 481 pages.

During the 35 years which have elapsed since the publication of Prof. R. A. Fisher's revolutionising book 'Statistical Methods for Research Workers', a number of statisticians belonging both to mathematical and biological disciplines, such as Snedecor, Goulden, Mather, and Panse and Sukhatme, have attempted to explain the handling of statistical tools to agricultural and biological research workers. This latest publication written to meet the same needs vividly reflects the considerable development which has taken place during the period and the large variety of complex tools which are today available. It also brings home to the reader the formidable task which confronts an agricultural research worker who wishes to familiarise himself with the array of methods of planning investigations and appropriately analysing the data furnished by the rapid advance in the theory of statistics.

The book comprises 22 chapters and 20 statistical tables. A brief history of the development of statistics and a discussion of scientific method and statistics are given in the Introduction. The next four chapters are devoted to the basic concepts in statistical methods and probability. In these chapters frequency distributions, random samples, graphical representation, methods of central tendency and dispersion, notion of probability, the normal distribution, test of significance, testing of hypothesis, power, confidence interval, comparison of means and variances are all introduced. The reader is, in addition, acquainted with the concept of linear additive model and Stein's two-stage sample procedure. The next chapter introduces the basic concepts in experimental designs. This is followed by two chapters on analysis of variance, dealing with 'one-way' and 'multi-way' classifications. A description of different methods of making individual treatment comparisons including Duncan's multiple-range test, Tukey's W-procedure and Dunnett's procedure, is a special feature of the first of these chapters. Assumptions in the analysis of variance, transformations, analysis of incomplete data are also dealt with in addition to the treatment of data from randomised block and latin square designs. Chapters 9 and 10 deal with linear regression and correlation. Chapters 14 and 16 are devoted to multiple and non-linear regression problems. These include the topics of intra-class correlation, computational procedures for multiple regression and orthogonal polynomials. Chapter 11 gives an introduction to factorial experimentation and the attendant problems of analysis. Linear models of fixed and random effects and the mixed model, variance components appropriate to them, concept of orthogonal comparisons, response surfaces and test for non-additivity find a place in the chapter. The next chapter deals with split-plot designs. Chapter 13 treats the subject of analysis of non-orthogonal data in two classes lucidly and at length. Chapter 15 is devoted to problems in analysis of covariance. After discussing the uses of χ^2 as applied to measurement data in Chapter 17, two chapters are devoted to the treatment of enumeration data. Chapter 20 gives uses of hypergeometric, binomial and Poisson distributions and the associated

tests. The next chapter introduces the reader to a few non-parametric procedures. The last chapter gives a short account of some of the elementary concepts in sampling finite populations. The numerous tables at the end are likely to prove extremely useful to the research worker obviating practically the necessity for reference to any outside source.

A welcome feature of the book is the numerous examples which have been given to illustrate the working details of the methods described. In spite of this, however, the book is so abundant of procedures that within the limitations of its present size it has not been possible for the authors to illustrate all of them. Possibly for the same reasons of space, the style is in some places rather terse and, therefore, a little difficult for a beginner to follow. As a matter of fact the book is more suited to be used as a handbook for ready reference by a biological research worker who has already familiarised himself with statistical methods through a more expository book. At the same time, although it may seem paradoxical, one cannot help noticing a few omissions in the book. Sheppard's corrections for grouping errors, the concept of confounding so useful in agronomic experiments, and Welch's test for testing means with heterogeneous variances may be mentioned. The grouping of subjects in different chapters and their order are rather unusual. The index at the end could have been more comprehensive. These are only a few points which could be mentioned but do not detract from the value of the publication as a reference book by a non-mathematical user of statistics already familiar with the subject in an elementary way. (V. N. AMBLE)

The Economics of Irrigation in Dry Climates. By COLIN CLARK (Published by the University of Oxford, Institute for Research in Agricultural Economics). Price 5 Sh.

Dr. Penman of Rothamsted has recently established a theorem that the water requirement of all crops grown on the same soil, and for the same period, should be similar. This upsets the age-long belief of each crop having its own 'Water requirement' and raises the ever important question of the economics of irrigation, because only judicious adjustment of water supply can ensure profitable returns. Best returns have been obtained in the U.S.A. by additional crop yields by the careful handling of irrigation water.

The problem of economics of irrigation deserves special attention in India because of her huge projects under different phases of construction. Quite a large portion of Indian soils depend on irrigation for producing crops. Rice is a crop which depends most on irrigation though showing only modest returns. Regulated supply of water to this crop, therefore, becomes very necessary to benefit by proper returns. Irrigation can, however, be practiced with advantage, in the case of mixed farming.

Statistical Tables presented in suitable places substantiate and lend clarity to the reading matter of this publication; of particular interest to an Indian reader is the caution implied by the author who feels that the irrigation will cost more and more in India with the passing of time.

This small publication is neat and compact, loaded with valuable information

on the economics of irrigation, particularly regarding India. It should prove of great value to Irrigation Experts, Planning Bodies and Engineering Departments. Citing of references at the end of the text following a set pattern would have further enhanced the value of this publication. (J.V.S.).

The Grass Cover of Africa. J. M. Rattray, 1960. F.A.O., Agric. Studies No. 49, Rome. Pages 168.

Grass in Africa, as elsewhere, needs preservation as it provides sustenance for livestock, and checks erosion. Thus, Rattray's study of the grass cover of Africa should prove of great utility to the African agronomist and agriculturist in shaping and planning the future of the vegetative cover on which policies of soil, forest and water are largely, if not exclusively, dependent.

In the ecological relationship of the grass cover the author briefly brings out the need for a knowledge of the vegetation of a place, particularly its grass components for efficient control of grazing, etc. The effect of climatic factors on grass cover are also discussed. Next, he discusses the method of presentation of a vegetation map with reference to an exhaustive grass map of Africa appended with the booklet. This map gives broad associations on a floristic basis. He further classifies the types of vegetation with which various grass communities are associated: i.e., forest and thicket, woodland, savanna, grassland, steppe and undifferentiated types. Successional changes are dealt with next with particular reference to shifting cultivation, grazing, over and understocking, etc. Reactions of the various *Themeda* types to heavy grazing and trampling are described at length. Next, he describes briefly 23 genera which he uses to differentiate the various associations. The last chapter deals with types of grass cover, state-wise.

Appendix A lists the grass cover types state-wise; B gives their geographical distribution. References cited and for further study are comprehensive. An index is provided for botanical names and it should provide general cross section of the vegetation to taxonomists.

The book is bound to prove of great use to the agronomist and those interested in comparative study of the management and maintenance of grasslands.—P.K.

Annual Report, 1959-60. Regional Research Laboratory (C.S.I.R.), Hyderabad. Pages 217.

The starting of a chain of National Laboratories has given ample opportunities for the scientists of India to show their mettle and use their technical knowledge for the development of science, particularly the applied part of it, for the benefit of our country. All the laboratories in the chain are doing very good work in their own spheres of interest. The Regional Research Laboratory of Hyderabad, being regional in character, concentrates its efforts on the utilization of raw materials and resources of the region, and renders help to the various industries of the area and beyond. The work of this laboratory is, therefore, diverse and varied in nature.

In the report under review are detailed the various projects undertaken by the members of the staff of the laboratory. Most of these relate to some industrial process or product, but at the same time the fundamental approach to industrial research is not lost sight of. Such an approach is necessary to make improvements in the existing process and to understand its technical problems in all its aspects.

The research activities of the year under review are grouped under (1) oil and fats, (2) surface coatings, (3) drugs and pharmacological researches, (4) essential oils and aromatic chemicals, (5) entomological studies on insecticides, (6) biochemical studies on the metabolism of proteins, nucleic acid and the microbiological preparation of citric acid and calcium gluconate, (7) fuels, (8) heavy chemicals and fertilizers, (9) ceramics, (10) hand made paper, (11) X-ray and physico-chemical studies, (12) study of industrial waters and (13) chemical and general engineering.

Besides these projects this institute was maintaining liaison with industry by providing them with information, assistance and advice and was also conducting surveys. Ten original papers and 16 reviews and popular articles have been published while several other papers were being prepared. The members of the staff also participated in symposia and the meetings of the various scientific bodies.

Three patents were accepted and ten were applied for.

On the whole good work is being done in the laboratory and its further achievements will be watched with interest. The report is printed on paper made in the laboratory by hand and the quality of the paper is quite good and has added to the nice get up of the report. The " errata " given at the end of this book is a bit too long and with a little more care and attention in editing, this could have been avoided.

—S.D.

The Grass Crop—its Development, Use and Maintenance. DAVIES, W. 1960. E. & F. N. Spon. Ltd., London. i-xvi, 1-363, p. 16.

The problem of grass has attained a universal appeal, and its importance in the modern agriculture and forestry need hardly be over emphasised. Its thorough study has been recognised as a prime factor in building up the permanent vegetative cover and for conserving the natural water resources practically everywhere in the world. It is under intensive study in many parts of the world and more and more is being known in the realm of grassland agronomy. Thus, the revised edition of the *Grass Crop* is timely and will prove of a great use to technicians, teachers, and students of agronomy.

The *Grass Crop* was originally written between 1946-50. Since then, considerable advances have been made in research on grassland, its development, use and maintenance; and Dr. Dave is to be congratulated on having incorporated an up-to-date account of the researches conducted on this important crop in this revised edition.

In Chapter I, the author states that he has aimed to bring together the available scientific evidence and practical experiences on nearly all aspects of grass crop, with particular references to its bearing on the livestock; and that he has treated the grassland as a stage in ecological succession.

He states that the permanent grass is a later facet in the succession than the ley. He also dilates upon the problem relating to establishment, early growth, persistency, management and grazing in leys. Under the Farming System he states that the modern technical achievements in relation to various farming practices and the modern technology have placed very useful knowledge in the hands of farmers; and discusses bearing of grass on sheep and cattle production. He states that animals induce changes in composition of the sward upon which they browse, and that even minor changes in management also alter the environment of pastures. The problems concerning the grazing season, composition of grassland and pasture and the choice of domestic animals with respect to sward, the bearing of various feeds on market production of milk and other characteristics of the livestock are discussed at length. Rotations of crops in pastures and their management is also described. Management of leys and permanent grass is briefly described. These are aimed at promoting a higher level of production.

In the Biotic Complex it is stated that the grassland is an elementary phase of vegetation and that in many countries, where forests have been cleared, the grasslands have been fenced and are thus under a new biotic influence. The effects of devegetation have had to desert condition. The rabbit is said to be an important element affecting biotic communities, the bearing of penguins on vegetation is also discussed in Falkland islands.

The author deals with the contrasting plant communities and vegetation forms in the world as a whole in the World: Forest and Grass. The forest of the world is divided into two main groups: the tropical or hill forest and the temperate or cold forest. The grasslands of the world are classified into savannah, steepe, desert, scrub and Alpine grassland. The desert of the world are divided into the hot desert of the tropics and the cold desert and tundra of Arctic climates. The role and the development of grazing lands under each class is shown in their proper perspective. In Ecology and Succession, the development of the present day grassland is traced from the forest land of the primitive times. The types of present-day grasslands are discussed next, with respect to their botanical composition, area, role in grazing, etc. The British Grasslands are divided into cultivated and uncultivated, and the most important types under each group are discussed. Botanical composition of various pasture types is tabulated. In the Permanent Grassland, problems relating to the grasslands are surveyed; and difference in potential production of ley as compared to the permanent grassland and as to how material improvement can be effected in permanent grass without ploughing are discussed. General management of marginal and Hill Lands with respect to pasture, tourism, etc., is also discussed. The Leys, their distinction from permanent grass and " rotation " grass, role in grassland maintenance, etc.; bearing on farming procedures, soil fertility; and establishment, including a discussion on whether the white grass seed should be drilled or broadcast, are dealt with in detail.

It is stated that short-duration ley has proved of great use for its grazing potential and that it is an essential crop. In the Nutrition of the Sward, the essential elements, concerned with the growth of herbage plants are divided into the major element, the

trace element and the minor element. The effect of their deficiency and restoration of the mineral plants in the sward have been properly described. This is followed by a discussion on Extending the Grazing Season, by seed mixture.

A detailed consideration of the following species and varieties available on world market and useful in Britain for both short and long duration leys are dealt with in Seed Mixture, ryegrass, cocks foot, timothy, meadow fescue, other grasses, legumes, white and red clover, lucerne, sainfoin and other legumes. The production of Herbage Seeds is discussed next; followed by lucerne and its potential use in Britain. Various groups of the commercial lucerne are described. Useful information has been given on agronomy of lucerne. This should prove of particular interest to the Indian agriculturists as it is very valuable fodder plant. So far the nutrient value is concerned, it is classed with such crops as sugar beet. In the Herbs of Grassland, it is stated that the herbs have considerable say in seed mixtures and provide an important element of grasslands. Chemical composition of certain herbs of lowland and upland pasture is tabulated. The penultimate chapter is devoted to the Grassland Terenity. Retrospect and Prospect form the concluding chapter. The author states that " there can be little doubt left in any body's mind that research and scientific method applied to farming is not only desirable but provides essential foundation upon which rapid progress can be built ". It is stated that lengthening of the productive capacity of our grassland is a major practical issue as the grasslands have since very early times provided fodder for domestic animals.

" It is our bounden duty to develop sound systems of farming that will cater for the demands for food while, at the same time, keeping our soils intact and in full health. " The ley and the grass crop are of fundamental importance in relation to this whole concept.

Seed Mixture in the Long Leys are enumerated in the Appendix and there is a comprehensive bibliography and index.—P.K.

Cane needs Fertilizer –

but More Cane needs More Fertilizer

The higher its sugar content the more valuable the cane. High yields take large quantities of plant foods from the soil. For nitrogen alone more than 200 kg. a hectare are removed. This removal of plant foods must continually be replaced if good yields are to be harvested. Experienced planters reckon to use 50 lb. of nitrogen per acre and 1 lb. for every expected ton of cane. Thus 150 lb. of nitrogen should be used for a yield of 100 tons of cane per acre. Jamaica, where fertilizers have raised yields by 130% and more, provides an example of what can be achieved with fertilizers. This shows the scope for expansion that still remains in the world's sugar-cane plantations. With the use of fertilizers this potential expansion can be realized. Everywhere it can be said: for every dollar spent on nitrogen, four dollars or more will be returned in the same season.

RUHR-STICKSTOFF AG supply nitrogen fertilizers and "RUSTICA" complete fertilizers, manufactured in numerous factories in Germany's largest industrial centre. RUHR-STICKSTOFF AG are one of the world's most important nitrogen exporters – their fertilizers contribute to the rising agricultural production of nearly 100 countries. Ruhr-Stickstoff fertilizers support the world's struggle against hunger.

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Instructions to Authors

Indian Journal of Agricultural Science is a quarterly journal. Articles of agricultural interest, based on original research, are accepted for publication. The manuscript, including legends for illustrations, graphs, etc., should be neatly typed (double space on uniformly sized paper) and sent in duplicate to the Editor (Research), Indian Council of Agricultural Research, Krishi Bhawan, New Delhi. The articles must be concise (not more than 20 typed pages). Adventitious material, relevant to doctorate thesis, should be excluded. A two-inch margin should be allowed on the left hand side of each page for editorial use. Normally, only one paper by one author will appear in a single number.

The articles sent for publication should be exclusive for this journal, and if the paper has appeared in an abbreviated form elsewhere (e.g. *Sci. & Cult.*, *Current Sci.* or *Nature*) this must be stated. Each article should have a brief summary of not more than 360 words. The hierarchy of headings being followed in the journal should be adhered to. Do not underline the headings. If the headings are intended to be serialized, use Arabic numerals or ordinary English alphabetical letters. Avoid footnotes, use of unusual symbols and elaborate tables (*they are expensive*).

In the case of botanical and zoological names, the International Rules of Botanical/Zoological Nomenclature should be strictly followed. Genetic and specific names must be underlined. In the case of a plant/animal which is not widely known, the name of the family should be given in brackets. The titles of journals should be abbreviated in accordance with the *World List of Scientific Periodicals*. The titles of books should not be abbreviated.

The references to literature, arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, the subject title, the abbreviated title of the publication, the volume and page numbers. A sample citation is as follows: Jodon, N. E. 1957. Inheritance of some of the more striking characters in rice. *J. Hered.* **48**(4): 181-92.

In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets, e.g., (Moore, 1951). When the author's name occurs in the text, the year of publication alone need be given in brackets, e.g., Moore (1929). Avoid cross references by page numbers.

The illustrations should be limited to the minimum considered necessary, and should be made with pen and indelible Indian ink. The photographs should be on glossy paper, at least of postcard size, and should be sent properly packed so as to avoid mutilation in transit.

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